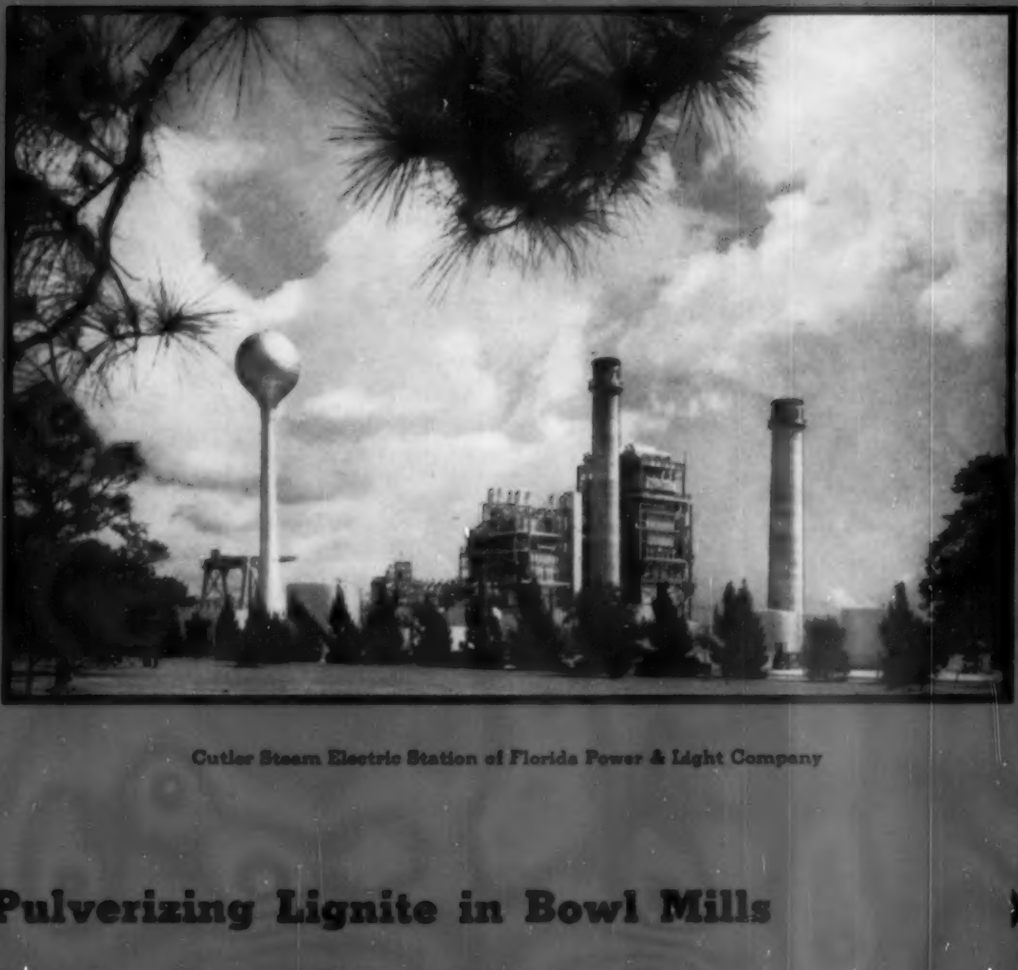
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

December 1954



Cutler Steam Electric Station of Florida Power & Light Company

Pulverizing Lignite in Bowl Mills

Service Record for Carbon Molybdenum Steam Pipe

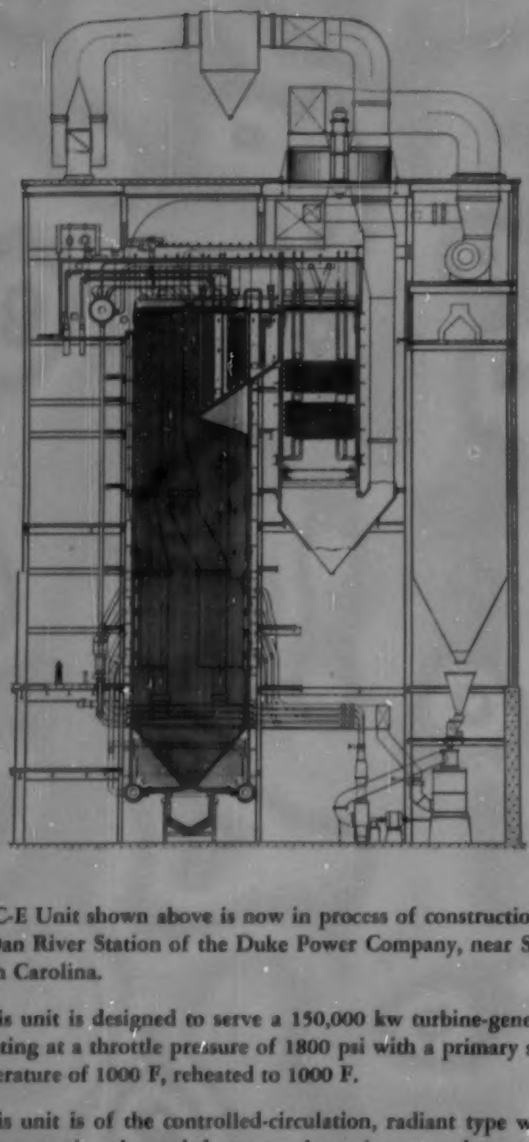
ASME Annual Meeting in Review

Fresh Water from Sea Water Evaporators

DAN RIVER STATION

Duke Power Company

C-E controlled circulation boilers



The C-E Unit shown above is now in process of construction for the Dan River Station of the Duke Power Company, near Spray, North Carolina.

This unit is designed to serve a 150,000 kw turbine-generator operating at a throttle pressure of 1800 psi with a primary steam temperature of 1000 F, reheated to 1000 F.

This unit is of the controlled-circulation, radiant type with a reheater section located between the primary and secondary superheater surfaces. An economizer section follows the rear superheater section and regenerative type air heaters follow the economizer surface.

Pulverized coal firing is employed, using bowl mills and tilting, tangential burners.

B-795

C-E

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

Vol. 26 No. 6

December 1954

Feature Articles

Editorials

Departments

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GERALD S. CARRICK
Business Manager

JOSEPH C. McCABE
Editor
GLENN R. FRYLING
Associate Editor

CARL G. UDELL
Circulation Manager

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BPA

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The New S·E·CO. Coal Valve
Can Eliminate Your Coal Valve Headaches

FOR EXAMPLE . . . it has *self-cleaning*, coined, ladder racks that cannot become clogged with coal, even on jobs having internal pressure. This feature alone can eliminate hours of time spent cleaning coal from the valve body, racks and pinions so that you can operate it.

. . . the pinions are also of *self-cleaning* design, located *above* the gate, an exclusive S-E-Co. design feature. This position helps keep the ladder racks clean and assures positive tooth engagement. This, together with the new husky sized racks, can eliminate your troubles with tooth breakage and subsequent time consuming repairs.

. . . large, 2-5/16" diameter, rollers, equipped with ball bearings, support the gate making sure it will move easily. These rollers have stainless steel shells to combat corrosion. Felt grease seals and stainless steel grease retainers with fittings for pressure lubrication insure their long life.

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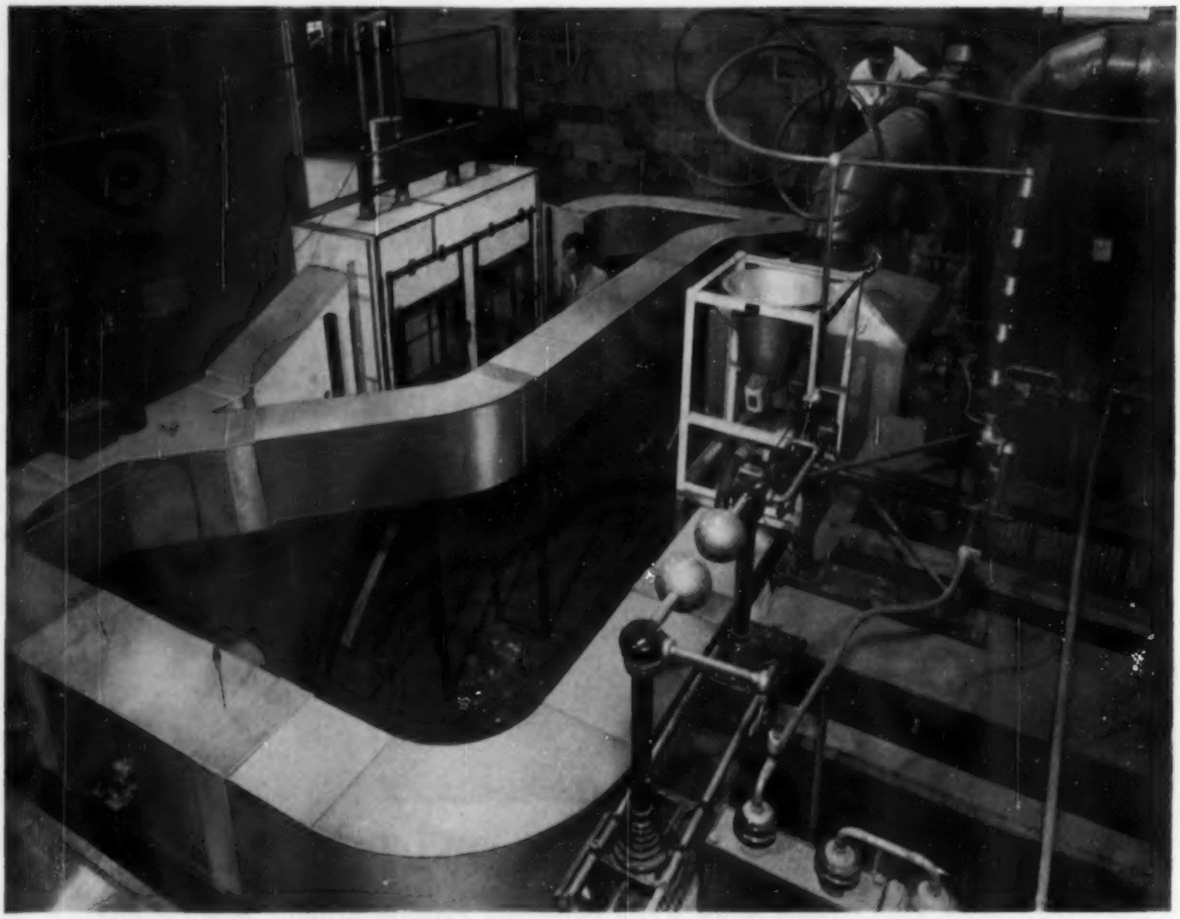

Precipitator pilot plant, Verona Research Center of Koppers Company, Inc.

Why Koppers Electrostatic Precipitators work so well

The answer to why Koppers Electrostatic Precipitators work so well is to be found in the sound engineering principles followed, from the project stage right through to actual installation . . . *application engineering "know-how."*

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Koppers also has extensive laboratory facilities to analyze plant processes and problems in industrial gas cleaning. It has pilot equipment and competent personnel to conduct conclusive tests.

It's this knowledge, this experience, these facilities that make for satisfactory service . . . service for which Koppers has long been famous.

Next time you have a gas cleaning problem, remember that every problem is different, every problem contains variables which must be correctly analyzed before a satisfactory solution is reached. So it will pay you to consult Koppers . . . the company with *application engineering "know-how."* Mail this coupon for additional information.

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HALL INDUSTRIAL WATER REPORT

Hall Laboratories, Inc.—A Subsidiary of Hagan Corporation, Pittsburgh, Pa.

Volume 2 DECEMBER 1954 Number 6

Close Control Pays Off in Clean Boilers

When Hall Service was started at an East Coast plant, R. A. Beardsley, service engineer, undertook to educate and interest all of the operating personnel in their water conditioning program, so that follow-through on his recommendations for better operation would not be left to "George." In this plant no actual failures had occurred, and because chemical treatment had been used, the personnel was convinced that such troubles as plugging of feed lines, poor distribution of chemicals, and the time and labor consuming cleaning job were necessary evils. The plant men were astonished when minor modifications in pre-boiler control and treatment practices, faithfully carried out, resulted in major improvements in the internal condition of four waste heat boilers.

Tight control now polices chemical treatment and adjustment of the phosphate-silica ratio in the boiler water has eliminated the adherent magnesium phosphate scale that was responsible for the massing of deposits.

Since the plant men had formerly taken it for granted that crowbars, chisels and hard labor were needed to get rid of heavy scale accumulations, washing out the greatly reduced amount of deposit right down to clean metal now seems like child's play.

Foreign Relations

One Hall staff engineer had to travel 8000 miles to go to work recently when a request for consultation came from the Arabian American Oil Company in Saudi Arabia. But setting up water treatment for boiler operation, for the protection of condensate lines and for air conditioning equipment at three plants made A. M. Henricks feel that he had never left home during the five weeks he spent in Arabia. Mr. Henricks' long-distance service job was one of several such trips he has made in the last few years.

Another phase of Hall Laboratories' foreign service is a training course which has been given to engineers and technicians from all parts of the world. Although this training is made available to Hall Laboratories' domestic clients, it is especially valuable to personnel from foreign plants in familiarizing them with the latest in water treatment.

Engineering and Industrial Wastes

In a Panel Discussion on Stream Pollution presented at the Fifteenth Annual Water Conference, H. A. Reda of Hall Laboratories defined "An Engineering Approach to Industrial Waste Problems." Viewing plant process and waste water problems as a part of an integrated program of water use leads to the systematic analysis that constitutes the engineering approach. Mr. Reda pointed out that "bonus" benefits frequently result when the investigator studies the entire water system in a plant in order to set up the most effective and economical treatment of industrial wastes. Recovery of costly process materials, reduction of water consumption, and re-use can help to offset the cost of treatment. In one plant, study of over-all water practices enabled Mr. Reda to reduce the preliminary $250,000 estimate by almost one half.

Mr. Reda's discussion brought out the value of the engineering approach in unraveling the complex waste disposal problems in plants built long before the pollution of streams was a consideration in industrial operations. In many of these older plants, no one actually knows how the piping is laid out. In some, where the water source is located on plant property, no measurement of flow rates has ever been made; probably such a plant would not even have a flow meter. In these plants, only an engineering approach can solve the problems effectively.

Hall Engineer Boosts Employee Morale

The several hundred employees of a glass manufacturing plant complained that hot water in the bath house was extremely hard and much too scarce. The shortage was due to a hard calcium carbonate scale which reduced shell-tube heater efficiency in a matter of days after each cleaning, and defied complete removal by either chemical or mechanical means.

When this unhappy situation was mentioned to Hall engineer W. J. Reese, he thought of the softened, Threshold-treated water used for make-up in the production cooling system in the plant. He pointed out that the blowdown from this cooling system, which had formerly run to waste, could be fed to the bath house heaters, thus eliminating the scale problem. Now everyone is happy . . . employees because they are getting adequate supplies of softened hot water, and management because a troublesome problem was licked without the purchase of costly water softening equipment.

Close Contact Maintained by Hall Executives

Field service engineers of Hall Laboratories get to boss the bosses when the top executives make their regular visits to all of the district offices to maintain first-hand contact with field problems. On such trips, even travel time is utilized for the exchange of information between the headquarters men and field engineers. When J. N. Welsh, Associate Director of Hall Laboratories, made the rounds of the western offices recently, one of his stops was at Nanaimo, where he presented a discussion on Steam Conditioning at a meeting of the Nanaimo Branch of the Institute of Power Engineers.

Water is your industry's most important raw material. Use it wisely.

HALL LABORATORIES, INC.—CONSULTANTS ON PROCUREMENT, TREATMENT, USE AND DISPOSAL OF INDUSTRIAL WATER

Stainless-Clad Steel Coal Shows No Wear After 9½ Years

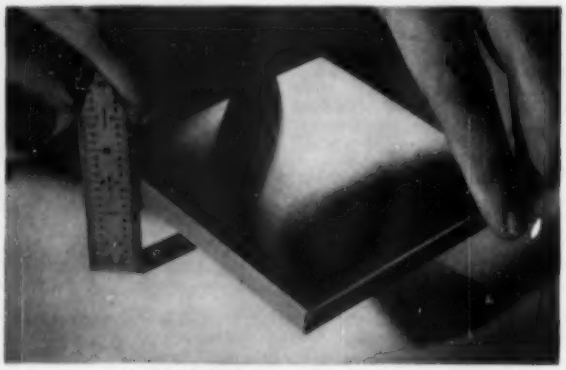
After 9½ years of continuous service without repairs, hopper #634 in Niagara Mohawk Power Corporation's Huntley Station has been removed for laboratory evaluation—still in perfect condition. This hopper, made of stainless-clad steel, had been installed in 1945 in an attempt to solve the problems of stoppages and hangups that cut into operating schedules and to relieve an expensive maintenance headache.

Its in-service record here proved Type 304 stainless-clad steel's economy and efficiency in withstanding the inevitable sulphuric acid corrosion and abrasive wear of moist coal. Laboratory examination of the hopper showed no measurable loss of gage, no repairs, and a far smoother interior surface than at the time of installation. Because of the exceptional performance of stainless-clad steel in this test hopper, it has since been specified for other coal handling equipment on the Niagara Mohawk system.

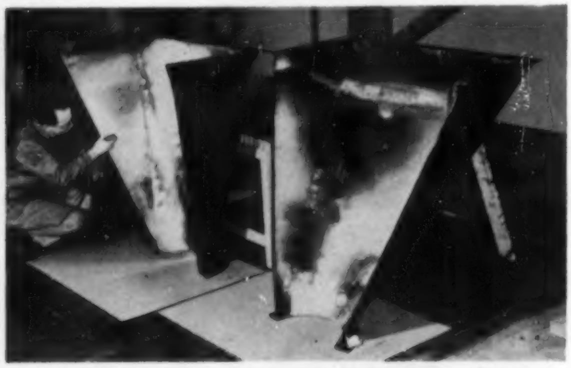
The reason is simple. Carbon steels ordinarily used in coal handling equipment lose as much as 25% of gage per year due to corrosion and abrasion, give very short service life. But stainless-clad steel affords *full* protection at *low* cost, develops a smoother surface with hard use.

Stainless-clad steel equipment means less maintenance, uninterrupted flow, and service life equal to that of a boiler. It gives you all the benefits of solid stainless plate with greater economy.

If you would like more information, write for Bulletin 740. In addition, our Technical Service Department is available to work with your equipment builders and engineers in putting stainless-clad steel to work for you. And, if you would like the names of qualified builders of clad steel coal handling equipment, write to the Manager, Marketing Service, 684 Lukens Building, Lukens Steel Company, Coatesville, Pennsylvania.



This photo shows a layer of stainless-cladding inseparably bonded by heat and pressure to the carbon backing plate. It provides the performance of the expensive solid stainless at a lower cost. In addition, clad steel can be worked by conventional fabricating tools and methods.



This is the original hopper #634, split in half for examination and testing. Even after 9½ years of rugged service, no loss of gage could be measured by laboratory instruments. Profilometer measurements of the stainless surface finish were 6 to 7.5 micro inches, the equivalent of a highly-polished finish.

LUKENS CLAD STEELS

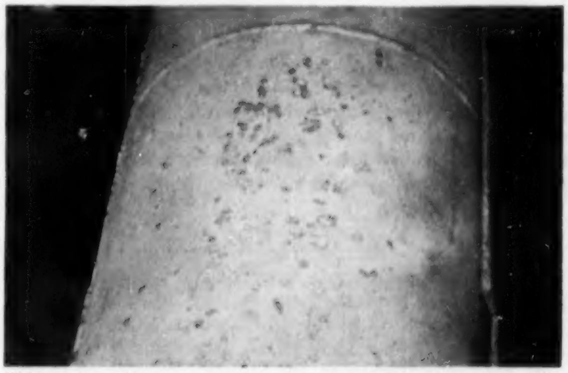
STAINLESS-CLAD

PRODUCER OF THE WIDEST RANGE OF TYPES AND SIZES OF CLAD STEELS AVAILABLE ANYWHERE

Hopper Service

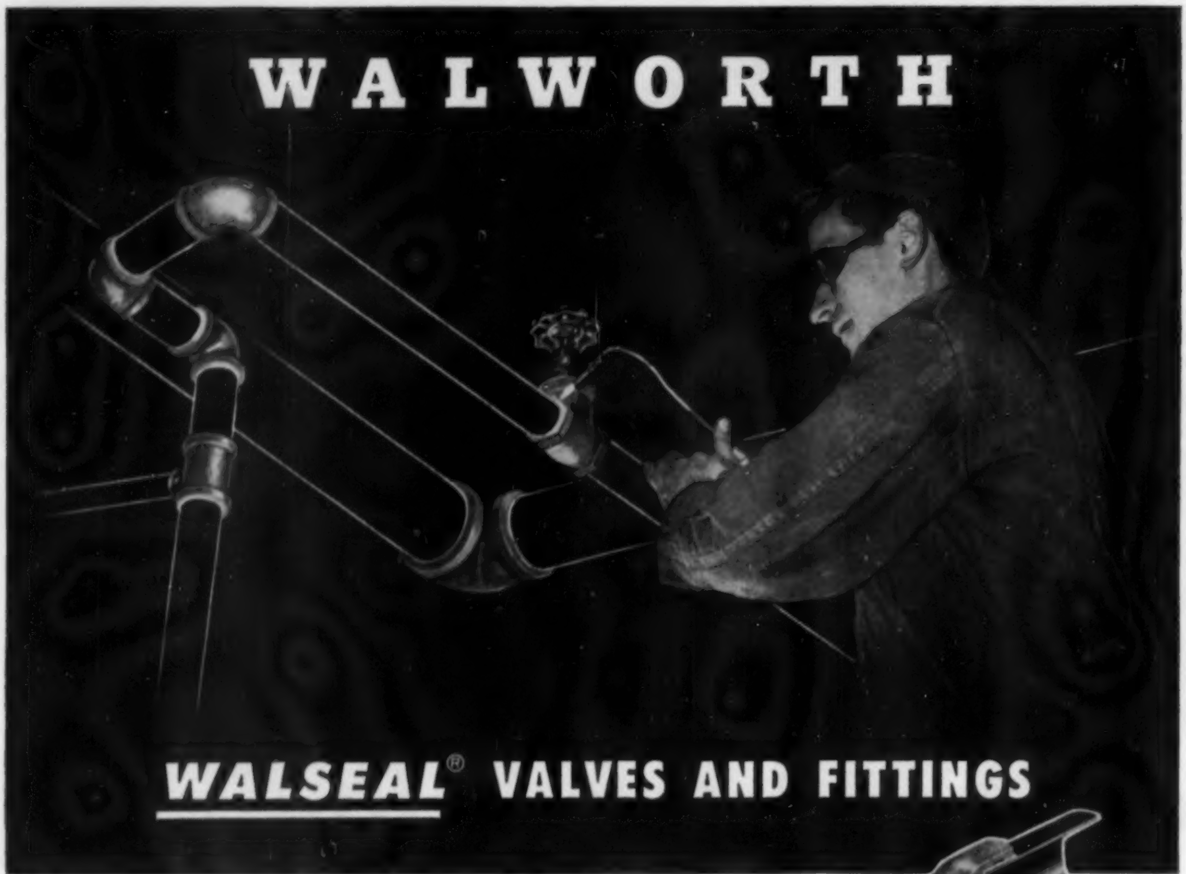
Pictured above are *four* stainless-clad steel hoppers in service at the Huntley Station of the Niagara Mohawk Power Corporation. Hopper #634 on the right is the recent replacement for the original test hopper that was removed for laboratory examination.

The failure of these relatively new carbon steel coal pipes, requiring patching as indicated by the "half-soles", had three *avoidable* results: flow was interrupted—high maintenance charges were incurred—service life was shortened. Stainless-clad steel would have eliminated the first two, and lasted through the useful life of the boiler.



This section of carbon steel coal pipe shows hammer marks made in freeing hangups due to rat-holing and arching. Smoother, corrosion-resistant stainless-clad surfaces reduce friction, help eliminate these causes of stoppage and high maintenance expense. These coal pipes at Huntley Station are now being replaced by stainless-clad pipes.

NICKEL-CLAD · INCONEL-CLAD · MONEL-CLAD



Better because **. . . There's no guesswork when a silver-brazed joint is made with a Walseal fitting. Sil-Fos alloy, which appears as a fillet at the face of a Walseal joint, comes from rings which have been factory-inserted in the end connections of Walseal fittings. The bright silver alloy fillet that you can see assures full penetration of alloy for a permanently leakproof joint.**

Cutaway view of a Walseal Tee showing: factory-inserted ring of silver brazing alloy; fillet of silver brazing alloy that appears upon completion of Walseal joint; cutaway view of the completed joint showing that silver brazing alloy has flowed in both directions from the factory-inserted ring.

Walseal is a registered trade mark which identifies valves and fittings manufactured by the Walworth Company. Walseal products have factory-inserted rings of silver brazing alloy in threadless ports. Walseal joints can be made only with Walseal valves and fittings.

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*Walseal fittings and valves are being used at sub-zero temperatures as low as —350 F.

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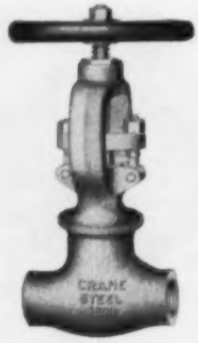

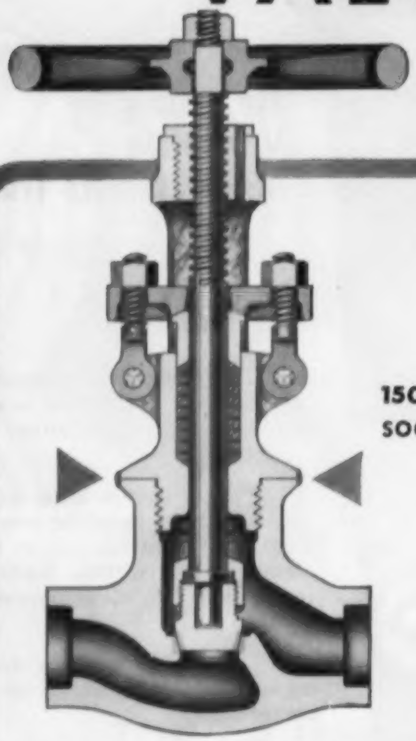

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SOCKET-WELDING AND SCREWED ENDS. SIZES ½ TO 2-INCH

What better way to seal against leakage at the bonnet joint of a small steel valve . . . than with a simple weld. And that's all the weld is ever called upon to do. Extra-long body-bonnet threads carry all mechanical loads—and at comparatively low stresses. Should dismantling be necessary, the seal weld may be repeatedly ground off—and reapplied—without damage to valve.

Right along with this modern Crane sealing principle go other important refinements. You get a compact, weight-saving structure without sacrificing strength or reducing seat area—a more rigid swivel disc-stem connection—durable Stellite-faced plug-type disc—and Stellite-faced integral seat.

Crane Lip-Seal Bonnet Valves are by far your best buy for high-pressure/high-temperature power services . . . worthy companions to the larger Crane Pressure-Seal Valves. Ask your Crane Representative for Circular AD1902, or write direct.

Lip Seal design is exceedingly simple. Body and bonnet are screwed together until a firm metal-to-metal contact is made between the smoothly machined flat surface on the shoulder of the bonnet and the top of the body. The small lips around the periphery are then seal welded.

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Welded-In Tubes in High Pressure Service... 7 years without a failure

One of the greatest problems in operating high pressure feedwater heaters in modern super-pressure power plants is failure of expanded tube joints. In 1947, Lummus pioneered the field in *welding* monel tubes to steel tube sheets in feedwater heaters. Two such units were built for the city of Lansing, Michigan, designed for 1200 psi. These units have had no failures in seven years of operation.

Lummus now has developed a procedure of welding copper nickel tubes to steel tube sheets. Subjected to terrific pressure and temperature tests, the welded units have gone through many cycles with excellent results. Lummus has also made one installation, in service now for over six months without a failure, having a design pressure of 2900 psi, and requiring over 30,000 70-30 cupro nickel tubes welded into steel tube sheets.

The unit shown above, with a design pressure of 2,600 psi, is being fitted with 70-30 cupro nickel tubes. Successful installations have also been made with 80-20 cupro nickel tubes.

Welding-in of tubes eliminates the possibility of tube joint failure because of fabricating inaccuracies, tube irregularities, nickel oxide deposits from annealing operations, and excessive tube hardness. Welding-in makes possible the use of heavy wall tubes which cannot be satisfactorily expanded.

Your inquiries are invited.

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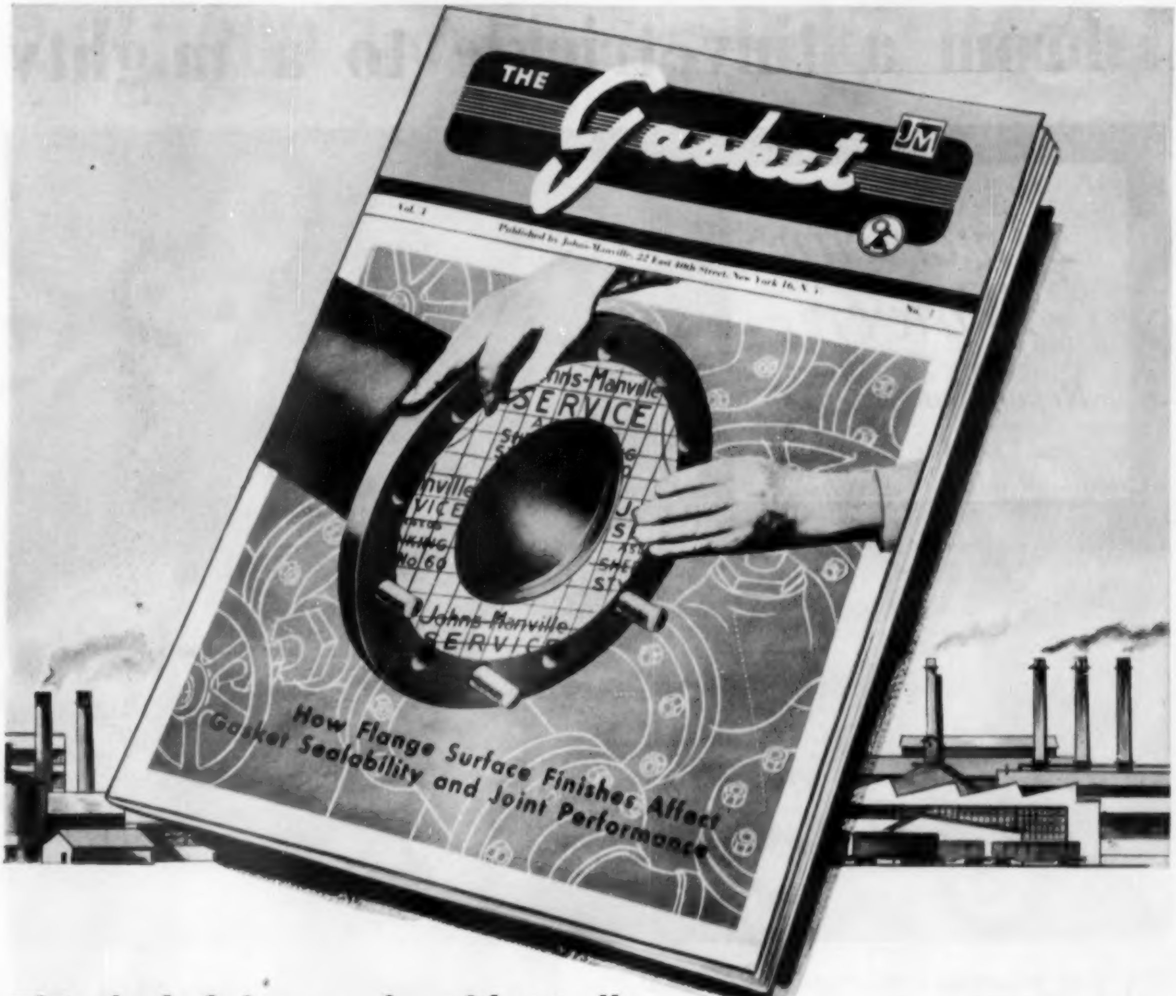
LUMMUS HEAT EXCHANGER DIVISION

LUMMUS

THE LUMMUS COMPANY HEAT EXCHANGER DIVISION, 385 MADISON AVE., NEW YORK 17, N. Y.



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How flange surfaces affect gasket performance

IF YOU BUY, specify or design joints requiring gaskets, you will find helpful information in this new booklet. It provides a basis for selecting the flange surface finish most suitable for a given gasket. It explains why the right finish makes it easy to form the initial seal and obtain the best joint performance in service.

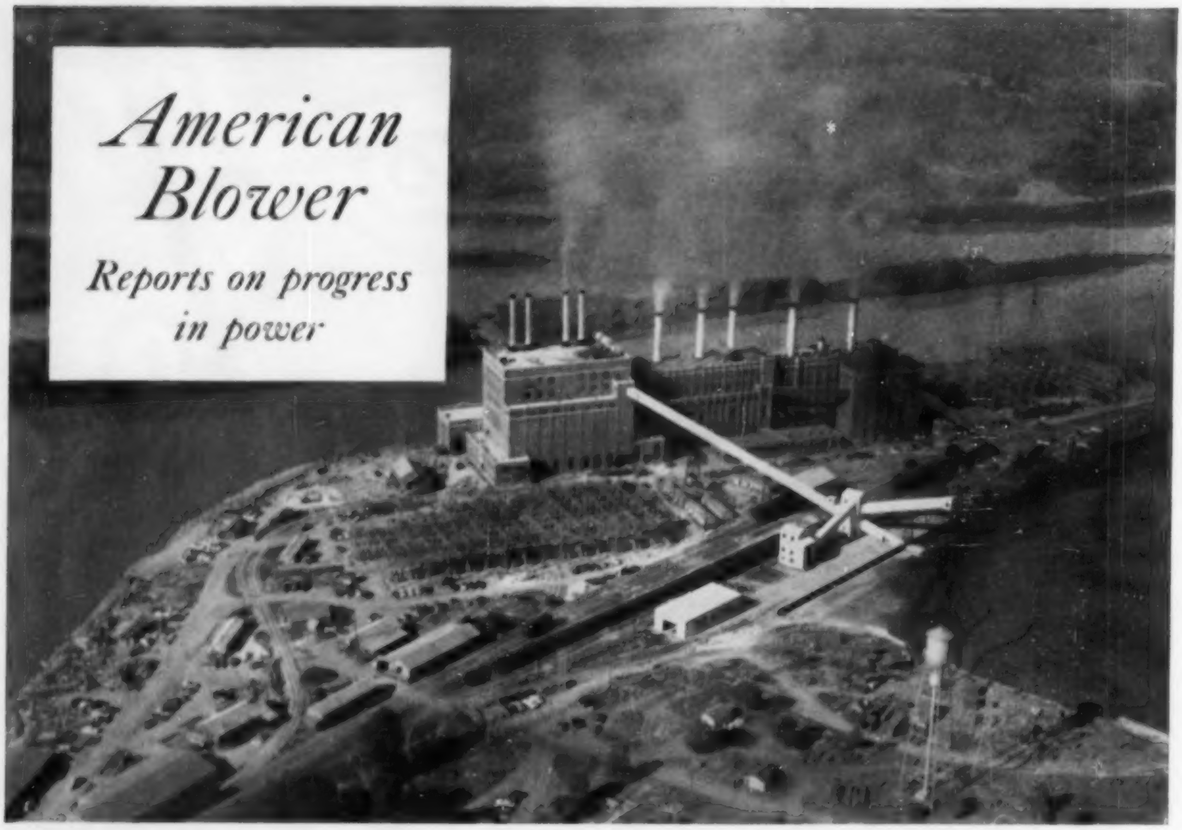
This booklet is the latest in a series of technical publications issued by Johns-Manville under the collective title "The Gasket." It is based on studies made at the Johns-Manville Research Center, largest laboratory of its kind in the world. It incorporates the long experience of Johns-Manville engineers in the design of gaskets such as asbestos, fibre and composition types, asbestos-metallic and all-metal gaskets.

Booklet offered without charge

To secure your copy of this study, write for "The Gasket," PK-48A No. 7. Address Johns-Manville, Box 60, N. Y. 16; in Canada, 199 Bay St., Toronto 1, Ont.

Johns-Manville PACKINGS & GASKETS

From a tiny trickle to a mighty

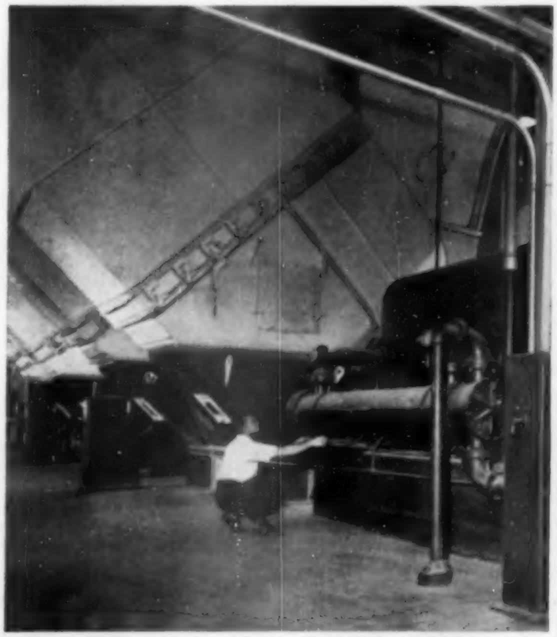


1. Duke Power's Buck Plant (above) near Salisbury, N.C., increased capacity by 250,000 kw in 1953. Two new generating units, recently completed, also added 266,000 kw to the Riverbend Plant near Charlotte, N.C. At the Dan River Plant near Draper, N.C., a new 150,000 kw unit is under construction, to be completed in 1955. Two other Duke Power plants are: Cliffside near Shelby, N.C. and Lee near Greenville, S.C.

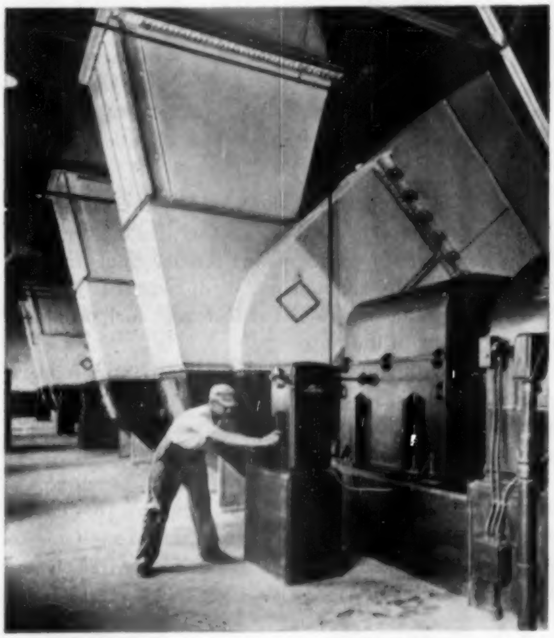
2. American Blower Gýrol Fluid Drive – type VS, class 6 – provides smooth, adjustable speed control of a boiler feed pump. It is coupled with a 1750 hp motor in the Buck Plant.

3. Four American Blower Forced Draft Fans are installed in Duke Power's Riverbend Plant. Each has a capacity of 143,000 cfm @ 100°F @ 1180 rpm @ 406 bhp.

2,211,000 kw–that's Duke Power!



4. Duke Power installed these four American Blower Induced Draft Fans at the Buck Plant. Each is driven through a type VS, class 4 American Blower Gýrol Fluid Drive.



5. Rated @ 234,000 cfm @ 296°F @ 637 bhp, each of these four American Blower Induced Draft Fans at the Riverbend Plant is coupled with an American Blower Gýrol Fluid Drive.

In its tremendous expansion, another leading power company chooses American Blower equipment

On April 1, 1904, a power line from a small hydroelectric plant at India Hook Shoals, S.C., was completed to Rock Hill, S.C. This was the simple beginning of the Duke Power Company system . . . a system that today serves over half a million customers in a 20,000-square-mile area in the Piedmont Carolinas – supplying electricity for some 35% of the nation's textile spindles . . . a system that through continued expansion will have an estimated capacity of 2,211,000 kw in 1955!

Planning far ahead of customers' needs is basic to this progressive, investor-owned utility. During the eight years from 1946 through 1953, Duke Power spent $231,000,000 to expand facilities, including $6,000,000 for the South's first steel-tower 230 kw line. Present plans call for additional expenditures, through 1964, of $30,000,000 annually. Duke Power is surging ahead with a dramatic fifty years of generating electricity behind them!

Supplying dependable air handling equipment and Gýrol Fluid Drives is the important part American Blower plays in Duke Power's tremendous expansion. (See pictures and captions.) It's a big role, one that is being duplicated in leading power and industrial plants everywhere.

If *your* future calls for expansion or modernization, talk over your plans and problems with an experienced American Blower representative. He can recommend efficient, economical equipment—including Mechanical Draft Fans, Fly Ash Precipitators, Dust Collectors, Heavy Duty Steam Coils and Gýrol Fluid Drives for boiler feed pump and fan control. Call your nearest American Blower Branch Office.

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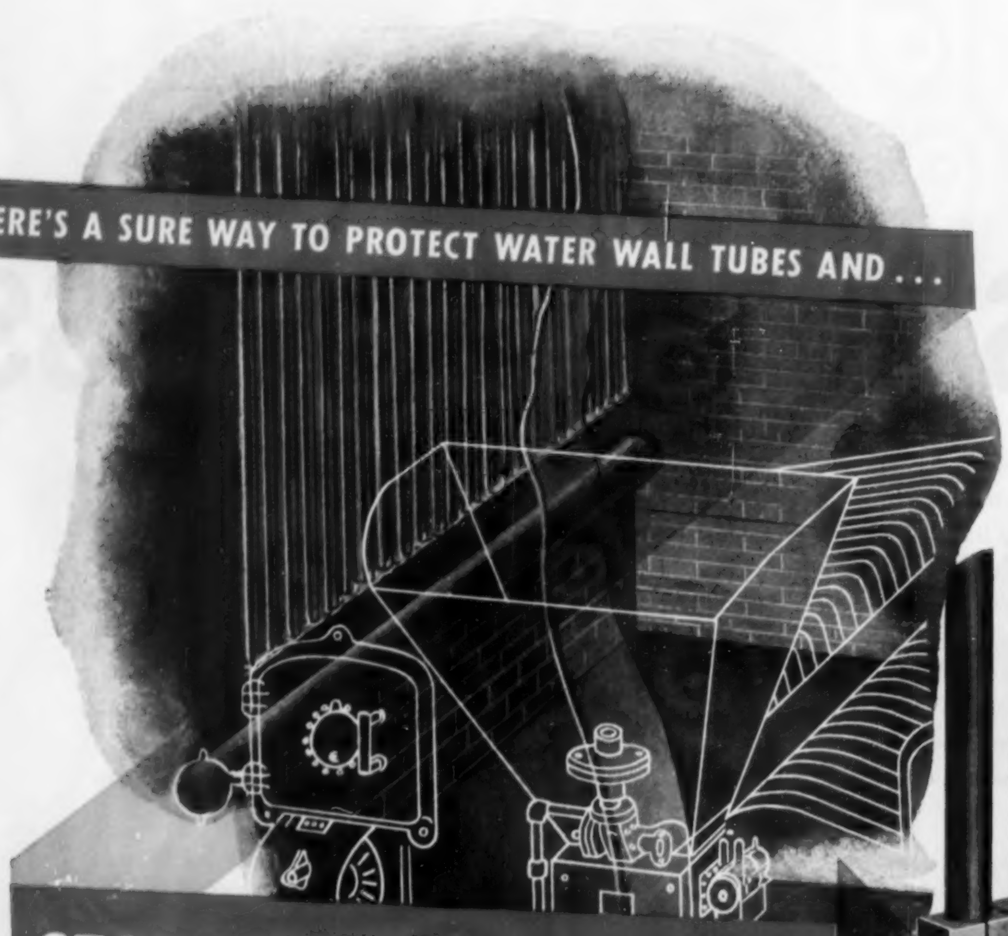


HERE'S A SURE WAY TO PROTECT WATER WALL TUBES AND . . .

STOP CLINKER BUILD-UP

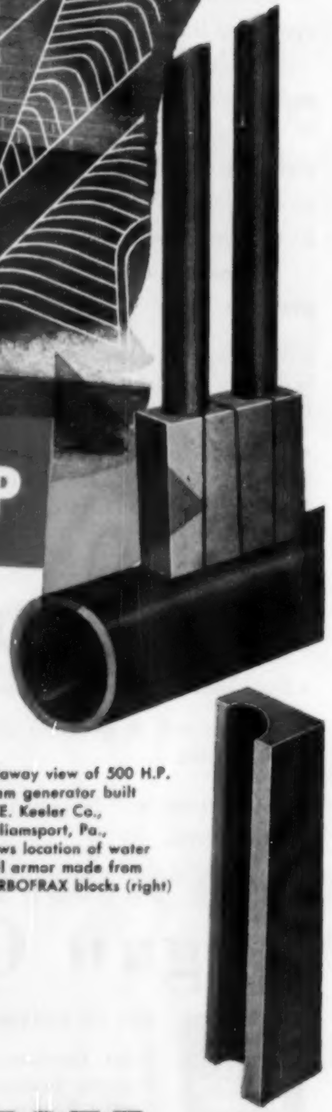
Here's a cure for two of the troubles that beset operators of stoker-fired water wall boilers.

E. Keeler Company, boiler manufacturer, has used CARBOFRAX® silicon carbide blocks, molded to fit snugly around the tubes where they connect to the headers. Since slag does not fuse to this hard, smooth material, these blocks prevent clinker build-up, protecting both the tubes and back-up lining.

The hot face of the CARBOFRAX blocks actually helps combustion. Ignition is maintained when the boiler is running at low and variable ratings. And abrasion by sharp coal particles makes so little impression that, after a test run of three years, the blocks were described by Keeler engineers as "showing no apparent wear on the furnace surface. We believe they will last almost indefinitely."

• • •

You'll find the answers to many problems of this sort in our free booklet, "Super Refractories for Boiler Furnaces." Address Dept. E-124, Refractories Div., The Carborundum Co., Perth Amboy, N. J.



Cutaway view of 500 H.P. steam generator built by E. Keeler Co., Williamsport, Pa., shows location of water wall armor made from CARBOFRAX blocks (right)

CARBORUNDUM

Registered Trade Mark


*FLEXITALLIC
FLEXITALLIC

COMBUSTION

Editorials

Observations at the ASME Annual Meeting

In searching for an analogy to the Annual Meeting of The American Society of Mechanical Engineers it is questionable whether the characteristics of a twelve-ring circus or the class schedule of a large university are more apt. Actually the 1954 meeting took on some of the aspects of both, for the scheduling of as many as twelve simultaneous sessions offered about as much intellectual fare at one time as Ringling Brothers, Barnum and Bailey ever proposed for the entertainment world. Nor is the fanfare absent, for ASME has become appreciably more publicity conscious and far more energetic in its dissemination.

But looking beneath the surface of a program that proclaimed record highs by reason of 124 technical sessions and nearly 350 technical papers, what do we find? One subjective impression from reading a substantial proportion of these papers is that the number of *significant* contributions of potential long-term technical importance is rather meager. In all too many cases quality has been sacrificed. To fill out a program that already may seem to be too full program-making agencies have had to solicit some papers that fall into one or more of these categories: (1) those previously presented before other groups, usually with enough modification to justify a slight change in title; (2) those that are on the borderline of commercial good taste, though Society review procedures should eliminate them; and (3) those representing such a narrow degree of specialization that they may be more appropriate for a division conference than for a general meeting.

To turn away from the technical side of the program, words of praise and appreciation are deserved by Lewis K. Sillcox for his inspiring leadership during his term as president of ASME. Those who have had an opportunity to talk with him are aware that the idealism and the humanitarian spirit that are an expected adjunct of Dr. Sillcox's addresses are equally a part of the man. He has shown by fine example that the materialism of engineering need not overwhelm the spiritual forces of human beings. It is extremely gratifying that a great professional and technical society should have that kind of leadership.

What has been written of the ASME Annual Meeting is intended in a spirit of constructive criticism. Many members of the Society as well as its capable staff are quite aware of the problems, some of which are closely akin to dilemmas. ASME now enters upon its 75th Anniversary Year, and there is every reason to believe that David W. R. Morgan, the incoming president, will guide the Society with the same wisdom and foresight that was exerted by its founders and perpetuated by the distinguished succession of ASME presidents.

Locating Suitable Power Plant Sites

The recently released Sixth Reports and Accounts of the British Electric Authority for 1953–1954 carried for the second year in succession a discussion of the difficulties facing the BEA in locating suitable power sites for new plant construction. Their difficulties, in the main, are not too different from those that plague U. S. power systems. But in one—the problem of ample cooling water—their problem is more acute. One phase of this cooling water problem particularly interested us because of its foreboding overtones.

In the 1953–1954 Report reference was made to an appeal on the part of the Authority to the Minister of Housing and Local Government for relief from restrictions threatened by a local river control group, the Yorkshire Ouse River Board, against a proposed new power plant. Briefly, local river boards came into being and were granted certain regulatory authority over the use of a discharge into individual streams in England at the time of the Rivers (Prevention of Pollution) Act of 1951 and its corresponding Scottish Act. The Act gives the appropriate River Board the right of consent, subject to certain definite conditions, before (1) any new or altered outlet for the discharge of trade or sewage effluent or (2) any new type of discharge can be made to a stream. In 1952–1953 difficulties arose with the Yorkshire Ouse River Board in connection with conditions attached to such consents, relating in the main to the degree of temperature at which water passed through the steam condensers should be returned to the river.

As a result of the Authority appeal the Minister, the Authority and the River Board agreed on an interim trial period during which detailed observations would be made to ascertain the effect of the discharge of warm water on river conditions. In the light of these observations final conditions as to discharge temperature will be determined.

The task of evaluating the complex chemical and physical effects that a warm water discharge has upon a river bed, its vegetable and animal life is extremely difficult. But over and above this apparent difficulty is the burden of setting a precedent. In fairness to all concerned the task should not be hurried. What's more the results should be thoroughly sifted, questioned and discussed before any recommendations are made. Here is one instance where local interests must be played down and the gravity of restrictions played up against the back drop of establishing a dangerous precedent.

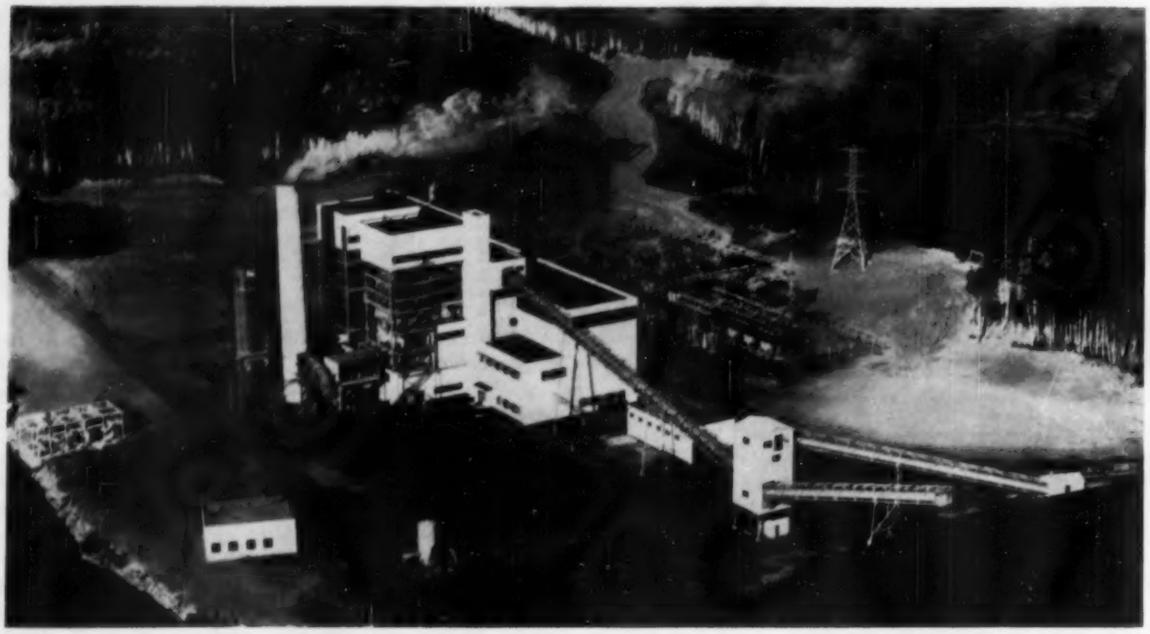


Fig. 1.—Aurora Steam Electric Station of the Minnesota Power & Light Co. where a steaming unit operating under typical load conditions, first on Western Kentucky coal, was transferred over to a Canadian lignite for performance test.

Standard Pulverizing Equipment

By ALEXANDER BOGOT

Combustion Engineering, Inc.

and

GEORGE E. GANDSEY

Combustion Engineering, Inc.

The greater fuel flexibility designed into today's steam generating units has equipped them to give creditable performance with fuels considerably outside any range originally envisioned. Here are some highly encouraging performance tests, established with lignite that was handled, prepared and fired by standardized equipment designed for bituminous coals.

THE power generating field is constantly seeking to reduce its energy costs and the lower grade, lower cost fuels carry a definite appeal on this count. Lignite is one such fuel that has become increasingly attractive in certain areas of the country. Many plants have proved it can be burned by one of several methods including pulverization. If the handling, preparation and combustion of lignite can be carried out with existing standard equipment then this fuel can be economically put to immediate advantage. The answer can only come from subjecting field equipment to test under typical operating conditions.

Equipment Description

Through the courtesy of the Minnesota Power & Light Co. a unit was made available at their Aurora Steam Electric Station, Fig. 1, to perform a number of highly significant pulverizing and burning tests using lignite as fuel. The test boiler was the No. 1 unit at Aurora, Fig. 2, a 3-drum boiler with standard pulverized coal burning equipment and tilting tangential burners, rated at 425,000 lb of steam per hr at 1350 psi and 955 F at the superheater outlet. Full steam temperature is guaranteed down to a rating of 300,000 lb per hr, with a final steam temperature of 930 F predicted at a rating of 250,000 lb per hr. A bypass damper augments the tilting burners for temperature control. At full load the air heater outlet air temperature available (no opening of the superheater bypass damper) is a predicted 553 F and at 350,000 lb per hr, a predicted 531 F. The furnace has one row of wall blowers above the burners and retractable blowers before both the primary and secondary sections of the superheater.

Three C-E Bowl pulverizers, each equipped with a 200-hp motor for driving the mill and its direct-connected exhauster, supply pulverized coal to the burners. The pulverizers are rated at 19,000 lb per hr on Western Kentucky coal having a Hardgrove grindability of 50 when grinding 70 per cent through a 200-mesh sieve.

Normally this coal has a heating value of 12,150 Btu per lb with 6 per cent moisture content. On the day a preliminary test was run at Aurora with Western Kentucky coal for comparison purposes against the subsequent lignite test runs, Table I, this coal showed a heat-

TABLE I—LIGNITE TESTS—MINNESOTA POWER & LIGHT CO., AURORA STATION

Boiler Data

Fuel (Test No. →)		1 W. Ky. Coal	2 Lignite	3 Lignite	4 Lignite
Steam Flow	M lbs/hr.	291	329	351	230
Water Flow	M lbs/hr	303	337	360	237
Sphtr. Outlet Press.	Psig	1308	1300	1324	1300
Sphtr. Outlet Temp.	°F	950	945	959	951
*Fdwtr. Temp to Econ.	°F	388	398	404	371
*Fdwtr. Temp from Econ	°F	488	505	524	483
Gas to Econ.	°F	833	996	—	—
*Gas to Air Heat.	°F	573/561	657/646	725/713	629/624
*Gas from Air Heat.	°F	284/292	328/325	334/338	313/316
Air from F.D. Fan	°F	75	80	81	79
*Air to Air Heat	°F	134/131	128/128	86/82	94/92
Air from Air Heat	°F	517/517	587/587	638/639	579/566
St. Air Htr. (F.D. Out) in Service		Yes	Yes	No	Yes
F.D. Fan Outlet Press.	"WG	4.3	6.1	7.5	3.0
Windbox Press.	"WG	5.7	1.6	1.6	0.3
Furnace Draft	"WG	0.35	0.35	0.40	0.40
Boiler Outlet Draft	"WG	3.0	3.0	3.5	2.0
Econ. Outlet Draft	"WG	4.5	5.0	5.9	3.2
Dust Collector Inlet Draft	"WG	6.1/5.7	7.0/6.6	8.3/7.9	4.5/4.1
I.D. Fan Suction	"WG	8.5/9.4	10.3/11.4	12.3/13.6	6.5/7.1
*CO_2 Air Heat. Inlet	%	14.1	16.7	15.3	15.5
*O_2 Air Heat. Inlet	%	4.7	2.8	4.3	4.0
*Excess Air Air Heat. Inlet	%	28	12	23	22
*CO_2 Air Heat. Outlet	%	13.0	15.5	14.4	14.1
*O_2 Air Heat. Outlet	%	6.0	4.1	5.3	5.5
*Excess Air Air Heat. Outlet	%	39	22	33	36
Series Damper	% Open	100	65	46	65
Shunt Damper	% Open	0	31	47	35
Burner Position	Degrees	−12	−14	−14	−14
Secondary Air Burner Dampers					
Upper Aux. Air	% Open	60	100	100	80
Upper Coal Air	% Open	40	0	10	0
Upper Center Aux. Air	% Open	60	80	100	80
Center Coal Air	% Open	40	0	10	0
Lower Center Aux. Air	% Open	60	80	80	50
Lower Coal Air	% Open	40	0	10	0
Lower Auxiliary Air	% Open	60	30	40	30

* Taken by test instrument, other readings taken from board.

Gives Good Performance With Lignite

ing value of 11,910 Btu per lb and a moisture content of 13.3 per cent, test No. 1, Table I. This departure from normal resulted from withdrawing the coal from storage during recent heavy snows. As compared with this usual fuel, a thousand tons of Canadian lignite of the analysis shown in Table III was brought in for the test runs.

Test Procedure

Three test runs, each of three- to four-hour duration, were made at 230,000, 329,000 and 351,000 lb per hr of steam while burning lignite. A preliminary test was run at 291,000 lb per hr while burning Western Kentucky coal, Table I.

Complete gas traverses of the air heater inlet and outlet were made to determine CO_2 and O_2. Thermocouples at the same points supplied gas temperature information. Thermocouples in test wells were used to determine the steam temperature and the feedwater temperature at the economizer inlet and outlet. A thermocouple traverse of the duct was run to obtain air temperatures entering the Ljungstrom air heaters.

All three mills were checked for test data. The complete information necessary for the calculation of a mill heat balance was taken, however, from the center mill only. This mill was chosen because it has a straight run of pipe at the exhauster discharge and would therefore give the most representative pulverized fuel samples. Moisture analyses of the fuel entering and leaving the mills were run during the tests, using the toluene method and collecting the moisture in a Dean-Stark tube. Mercury thermometers were used for all mill temperatures. Pitot tube readings for measurement of air flow were taken in the hot air duct to the mill.

Samples were taken above the feeder every half hour for analyses of the raw fuel. The dust collector hoppers and furnace bottom furnished fly-ash samples for combustible determination, Table III.

Pulverizer Mills

The three Bowl mill pulverizers had been in service from 3500–6900 hrs at the time of the test. The center mill which serves the center set of burners was the mill with the greatest number of hours. The relative light loading of the mills during their first year of operation is due to the fact that the station makes up capacity only over and above that generated by water power.

Although an initial inspection showed some wear on the grinding elements in the pulverizers, no adjustments of roll to ring clearance was deemed necessary. Grinding pressure for the first test run on lignite was the same as that used on the Western Kentucky coal.

After the changeover from Western Kentucky coal to lignite external adjustments were made to the classifier vanes to bring the fineness down to the desired amount. When the first test run was over the roll pressure springs were externally adjusted with the mills in operation to increase the grinding pressure. Power requirements dropped a little with this change in compression.

At 351,000 lb per hr of steam output the mills ground 22,050 lb per hr of lignite at 65–68 per cent through the 200-mesh with 3–4 per cent on the 50-mesh and used 89.4 per cent of the full motor load hp for a mill power requirement of 13.5 kw per ton. During this, the highest rating attempted with lignite, mill outlet temperature ran 125 F. The lignite moisture content measured 36.4 per cent entering and 28 per cent leaving the mills.

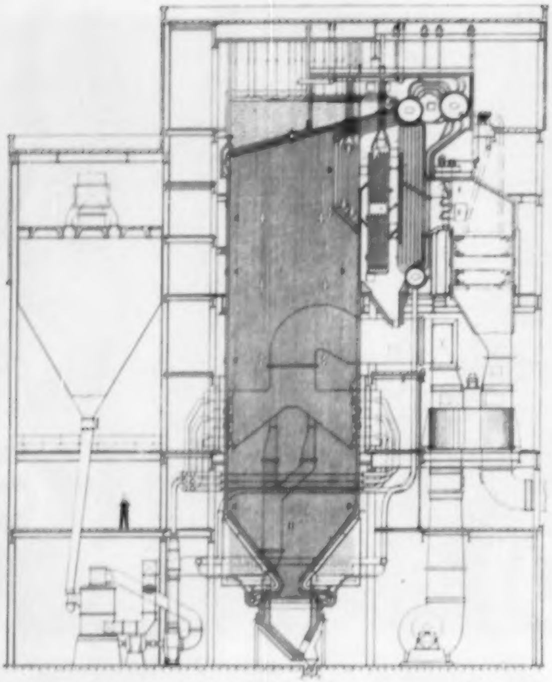


Fig. 2—Cross-sectional drawing of Unit No. 1 at Aurora Station. It is designed for 425,000 lb of steam per hr at 1350 psi and 950 F using bituminous coal. There were three lignite test runs made with the highest at 351,000 lb per hr.

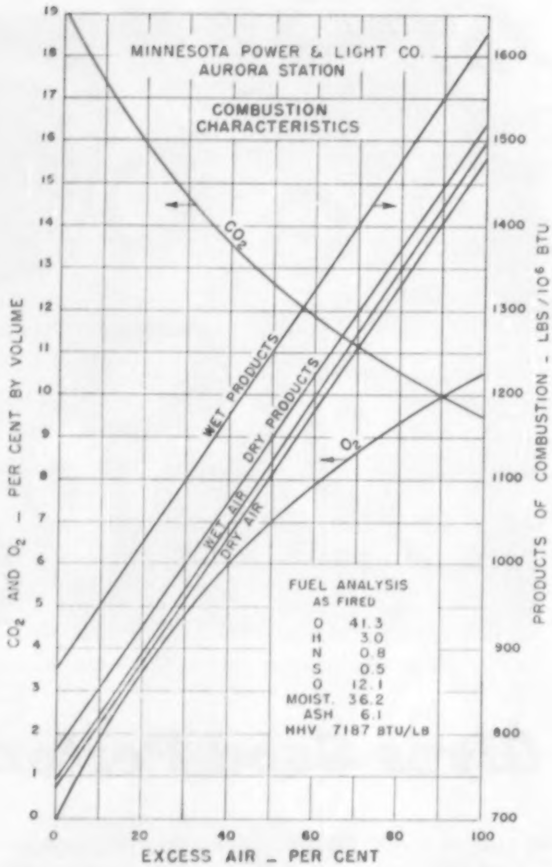


Fig. 3 Combustion characteristics produced by different excess air supplies during the lignite test runs curves, right.

The relative humidity of this coal-air mixture was 81 per cent. Absolutely no difficulties occurred in handling this material.

Table V lists the results of the heat balance calculations worked up from test data on the center mill of the No. 1 unit at Aurora. Certain assumptions, though, had to be applied in these calculations. First, a constant of 13 Btu per lb of fuel was used for the heat of grinding. Further, the air leakage and tempering air were not measurable. These values were obtained by measuring the hot air, obtaining the total air flow by moisture balance and getting leakage air by the difference. In addition, radiation losses were figured at 5 per cent of the heat input on the basis of previous heat balance tests on bowl mills.

The unaccounted for heat input to the pulverizers varied considerably between tests. This, however, could be the result of slight errors in the radiation loss, the above assumptions and in the moisture analysis. For example, a 1 per cent change in moisture content of the fuel entering or leaving the mill would make about a 10 per cent change in the unaccounted for heat input.

Boiler and Air Heater

The curves in Fig. 5 show test data for boiler performance with lignite firing compared to C-E predicted performance with coal. A single point on these curves also indicates the data obtained on the equipment under a preliminary test run using Western Kentucky coal. Table I includes the data for all curves in Fig. 5 as well as all other data obtained during the tests.

The single point Western Kentucky coal preliminary test falls very closely in line with the manufacturer's predicted performance curve. On lignite, however, gas temperatures run above those predicted for coal. This resulted from the greater mass flow over the superheater at any given load making it necessary to bypass some of the gases around the superheater surface to maintain a constant steam temperature.

Table IV contains the boiler heat balance calculations. These were calculated on the million Btu basis according to the ASME method with credit allowed to the steam air heater.

Unfortunately at the time of the tests it was impossible to pull ashes before each of the three runs with lignite. The only set of ash samples for lignite was obtained on the ash accumulated during the test run at 351,000 lb per hr of steam output. As a result the combustible found in this set of samples was used in the heat balance calculations for the other two runs on lignite. However, the per cent of combustible in this one set of ash samples was so low that possible variations during the other two runs would not have made any practical difference in the overall efficiency.

During the check run on Western Kentucky coal the overall efficiency reached 89.0 per cent, or about 0.65 per cent above that predicted for this rating. For the three runs on lignite the efficiency averaged 83.5 per cent.

TABLE II—LIGNITE TESTS—MINNESOTA POWER & LIGHT CO., AURORA STATION

Bowl Mill Data

Test No. →		1			2			3			4		
Mill No. →		A	B	C	A	B	C	A	B	C	A	B	C
*Mill Suction	"WG	2.0	2.8	2.5	0.4	0.5	0.9	0.8	0.7	1.1	1.9	2.1	2.1
*Separator Top Suction	"WG		6.5			6.1			6.0			6.3	
*Convertor Head Out. Suct.	"WG		8.7			8.6			8.4			8.5	
*Exhaust. In. Suct.	"WG		10.4			9.1			8.4			9.8	
*Exhaust. Discharge. Press.	"WG	8.3	7.8	7.4	10.5	10.3	10.0	11.9	11.6	11.3	9.6	9.0	9.0
*Tempering Air Temp.	°F Dry Bulb		82			78			79			82	
*Tempering Air Temp.	°F Wet Bulb		62			57			58			62	
Rel. Humidity Cold Air	%		30			24			25			31	
*Air to Mill Temp.	°F Dry Bulb		508			582			630			561	
*Air to Mill Temp.	°F Wet Bulb		147			144			177			176	
*Mill Outlet Temp.	°F Dry Bulb		161			124			125			135	
*Mill Outlet Temp.	°F Wet Bulb		106			116			119			120	
Rel. Humifity at Mill Out.	%		18			80			81			62	
Moist Fuel to Mill	%		13.2			37.0			36.4			35.6	
Moist. Fuel from Mill	%		3.0			29.8			28.0			25.0	
*Fuel to Mill Temp.	°F		48			58			56			59	
Mill Amps		160	163	143	208	208	213	193	204	199	155	155	164
Mill Voltage			466			468			468			470	
Mill Kw Input		116	117	104	151	151	155	140	148	145	114	114	120
Mill Kw/Ton			22.25			15.4			13.5			16.3	
Classifier Vane Setting		2 2/3	2 2/3	2 2/3	2	2	2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2	1 1/2
Fineness: On 50-Mesh		0.4	0.5	0.4	2.1	2.5	1.6	4.0	4.0	3.2	2.4	3.6	3.2
Through 100-Mesh		93.6	93.2	94.7	84.2	85.0	86.8	79.7	83.2	84.5	84.7	83.0	81.3
Through 200-Mesh		73.0	72.2	75.8	65.3	67.5	68.1	65.2	68.4	68.4	67.2	66.5	62.5
Spring Compression	Inches	13/16	13/16	13/16	13/16	13/16	13/16	1 1/8	1 1/8	1 1/8	1 1/8	1 1/8	1 1/8
Exh. Inlet Damper	% Open	65	65	65	95	95	95	100	100	100	65	65	65
Hot Air Damper	% Open	65	65	65	100	100	100	100	100	100	100	100	100
Tempering Air Damper	Position		2" Open			Closed			Closed			Closed	
Tramp Iron Spout	Position		Closed			Closed			Closed			Closed	

* Taken by test instrument, other readings taken from board.

The major difference, as expected, could be charged to the additional loss from the moisture in the lignite (H_2 + H_2O), which was almost double this same loss on coal.

The total steam temperature when burning lignite at a boiler output of only 70,000 lb per hr was 900 F with the burners tilted up 27 degrees. With the bypass dampers closed, full steam temperature of 950 F was obtained at 100,000 lb per hr on lignite and at 175,000 lb per hr on Western Kentucky coal.

At the time of the boiler performance study a check was made on the air heater balance, Table IV. Using the ratio of air temperature rise to the total heat head available (gas temperature to the heater less air temperature to the heater) at the 351,000 lb per hr rating an actual air heater efficiency of 86.8 per cent was obtained for coal and 86.2 per cent for lignite as against a predicted 86.4 per cent for coal.

Burners

The relative positions of the coal-air and auxiliary-air windbox dampers were changed when the transfer from Western Kentucky coal to lignite was made. This damper change controlled the location of the ignition point for the fuel-air mixture leaving the burners. For example with the coal-air dampers closed (leakage air only past the dampers) the ignition took place about 12

TABLE III—LIGNITE TESTS—MINNESOTA POWER & LIGHT CO., AURORA STATION

Laboratory Analyses

Canadian Lignite

Proximate Analysis (as Fired)		Ultimate Analysis (as Fired)	
Volatile	28.0%	Carbon	41.3%
Fixed Carbon	29.7%	Hydrogen	3.0%
Moisture	36.2%	Nitrogen	0.8%
Ash	6.1%	Oxygen	12.1%
		Sulfur	0.5%
Btu	7187	Moisture	36.2%
Sulfur	0.5%	Ash	6.1%

West Kentucky Coal

Proximate Analysis (as Fired)		Ultimate Analysis (as Fired)	
Volatile	32.4%	Carbon	65.9%
Fixed Carbon	48.2%	Hydrogen	4.7%
Moisture	13.3%	Nitrogen	1.3%
Ash	6.1%	Oxygen	6.3%
		Sulfur	2.4%
Btu	11910	Moisture	13.3%
Sulfur	2.4%	Ash	6.1%
Hardgrove Grindability	60		

Unburned Carbon

	Lignite	W. Ky. Coal
Dust Collector	1.2%	6.5%
Furnace Bottom	1.7%	2.8%

TABLE IV—LIGNITE TESTS—MINNESOTA POWER & LIGHT CO., AURORA STATION

Boiler Heat Balance

Test No. →	1	2	3	4
Fuel →	W. Ky. Coal	Lignite	Lignite	Lignite
Dry Gas Loss	6.11	5.67	6.41	6.13
H_2 & H_2O	5.40	10.01	10.28	10.23
H_2O in Air Loss	0.04	0.05	0.04	0.04
Radiation Loss	0.58	0.50	0.50	0.72
Carbon Loss	0.32	0.13	0.13	0.13
TOTAL	12.45	16.36	17.36	17.25
Steam Air Heater Credit	1.43	0.99	—	0.49
TOTAL LOSSES	11.02	15.37	17.36	16.72
Efficiency	88.98	84.63	82.64	83.24

Air Heater Balance

		1	2	3	4
Excess Air at Air Heater Inlet	%	28	12	23	22
Excess Air at Air Heater Outlet	%	39	22	33	36
Air in Products Ent. Air Heater	Lb./10^6 Btu	985	837	919	912
Wet Products Ent. Air Heater	Lb./10^6 Btu	1063	967	1050	1042
Wet Products Lvg. Air Heater	Lb./10^6 Btu	1147	1042	1125	1147
Leakage	Lb./10^6 Btu	84	75	75	105
Air Weight through Air Heater	Lb./10^6 Btu	783	669	762	707
Air Heater Leakage	%	8.5	9.0	8.2	11.5
Air through Air Heater for Combust.	%	79.5	79.9	82.9	77.5

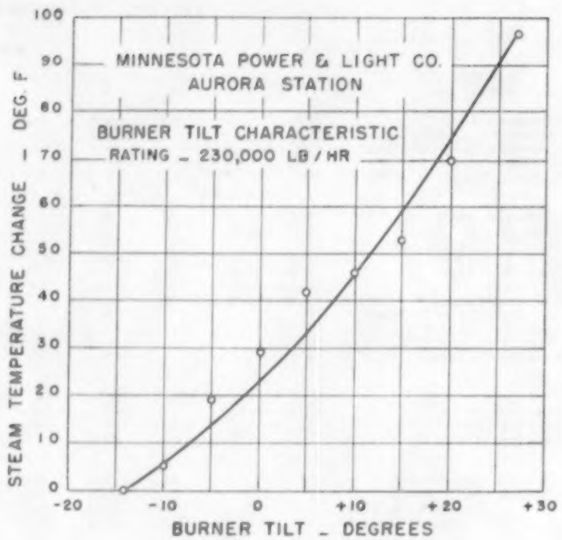


Fig. 4—Burner tilt characteristic curve reflecting the change in steam temperature with change of burner tilt.

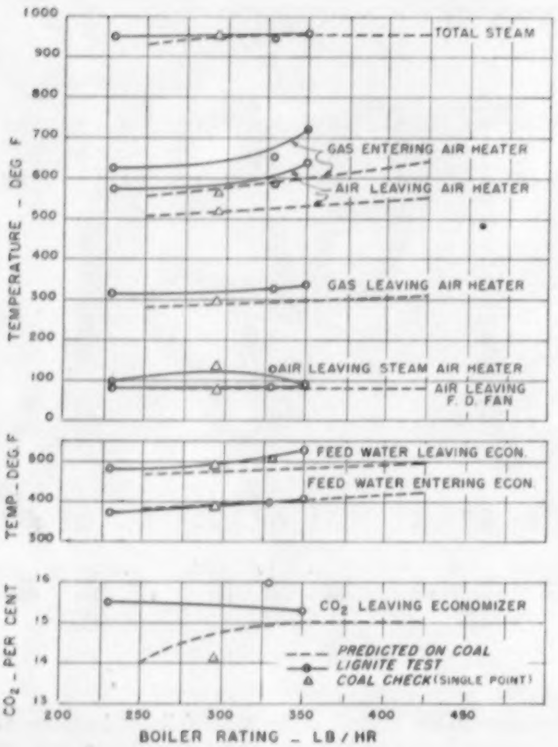


Fig. 5—Performance test curves for equipment on No. 1 Unit at Aurora with lignite, a single, actual coal comparison check, Table I, and predicted values, left.

to 18 in. out from the burner tips. By opening the coal-air dampers this point of ignition could be moved in or out at will. Flame stability proved excellent and combustion of the fuel was rapid and complete.

At 351,000 lb per hr output and with about 20 to 25 per cent excess air entering the air heaters there was no visible flame above the lower drum elevation. There was a rather sharp drop off in rating on the unit at night, down to 70,000 lb per hr output with only two mills (eight burners) in service through the night. No supplementary fuel was needed either by use of the main oil guns or the side pilot igniters at this low load. The fires were very stable and based on observed results two mills in service would give a load range of $4^1/_2$ to 1 on this fuel. By going to one pulverizer in service it is possible to anticipate an overall unit range of 8 to 1 without the use of the side pilot igniters.

Throughout the test runs there were absolutely no evidences observed of any drifting or accumulations in the fuel piping, nozzles or burners.

A burner tilt characteristic was run on lignite while the boiler was operating at a rating of 230,000 lb per hr. The burners were moved from a down tilt of 14 degrees to an up tilt of 27 degrees during which time the steam outlet temperature changed 97 degrees F. Fig. 4 shows the tilt characteristic curve. No flame nor incandescent particles were observed at the furnace outlet at this 27 degree upward tilt.

TABLE V—LIGNITE TESTS—MINNESOTA POWER & LIGHT CO., AURORA STATION

"B" Mill Heat Balance

Test No. → / Fuel →		1 Coal	2 Lignite	3 Lignite	4 Lignite
Unit Heat Output	10^6 Btu/hr	321.3	358.3	383.0	258.1
Unit Efficiency	%	89.13	84.63	83.64	83.24
Unit Heat Input	10^6 Btu/hr	360.5	422.8	463.0	309.6
Unit Wt. Fuel Fired	lbs/hr	30,270	59,610	64,420	42,700
Spec. Humidity Air Ent.	lbs H_2O/lb Air	0.0036	0.0042	0.0032	0.0039
Spec. Humidity Air-Coal Lvg.	lbs H_2O/lb Air	.0386	0.0717	0.0777	0.0785
Wt. Mill Fuel	lbs/hr	10,590	19,710	22,050	13,960
Wt. Moisture in Fuel-Ent.	lbs/hr	1398	7293	8026	4970
Wt. Dry Fuel	lbs/hr	9192	12,417	14,024	8990
Wt. Moisture in Fuel-Lvg.	lbs/hr	284	5271	5454	2997
Wt. Moisture Loss in Fuel	lbs/hr	1114	2022	2572	1973
Wt. Dry Air	lbs/hr	31,850	29,960	34,250	26,450
Wt. Air Ent. Mill-Pitot	lbs/hr	27,850	29,680	31,000	23,850
Wt. Air Leakage & Tempering Air	lbs/hr	4000	280	3250	2600

Test No. →		1	2	3	4
Heat Given by Air	10^6 Btu/hr	2.415	3.509	4.017	2.600
Heat Given Due to Grinding	10^6 Btu/hr	0.138	0.252	0.287	0.181
Heat Given—Total	10^6 Btu/hr	2,553	3,761	4.304	2.781
Heat to Evap. Moisture in Fuel	10^6 Btu/hr	1.213	2.199	2.798	2.146
Heat to Raise Evap. Moisture to Temp.	10^6 Btu/hr	0.056	0.045	0.070	0.058
Heat to Raise Fuel to Temp.	10^6 Btu/hr	0.326	0.211	0.270	0.186
Heat to Raise Moisture in Fuel to Temp.	10^6 Btu/hr	0.032	0.285	0.333	0.198
Heat to Raise Leakage Air to Temp.	10^6 Btu/hr	0.077	0.002	0.030	0.027
Heat Lost Due to Radiation	10^6 Btu/hr	0.127	0.188	0.215	0.139
Heat Lost—Total	10^6 Btu/hr	1.831	2.930	3.716	2.754
Heat Unaccounted for	10^6 Btu/hr	0.722	0.831	0.588	0.027
% Heat Unaccounted for	%	28.2	22.1	13.7	1.0

Visual observation of the furnace outlet and ashpit showed absolutely no sparklers or glowing particles at any time during the lignite runs, either in the ashpit or leaving the furnace. Table III indicates carbon contents below 2 per cent for combustible samples taken from dust collector hoppers and furnace bottom. As reported earlier, during the various tests the lignite was ground to 65–68 per cent through the 200-mesh sieve with 2 to 4 per cent on the 50-mesh. However, for one period of about an hour, the pulverizers were grinding to only 51–54 per cent through the 200-mesh with 9 per cent on the 50-mesh sieve. Even during this period the furnace looked excellent with no large sparklers visible.

Furnace

The wall soot blowers were operated before, but not during, all of the lignite runs. After protracted operation with the burners at the downward tilt an ash accumulation of a very light, spongy nature was found on the furnace walls. This was easily removed. Changes in rating and burner tilt position produced a very noticeable and definite peeling and sloughing off of the accumulated ash.

Furnace exit gas temperatures were not measured. The units at Aurora have a heat release rate of 81,000 Btu per sq ft, eprs, based on 6585 sq ft, eprs. The rate of accumulation of ash on the front furnace walls and front bank of boiler generating tubes would indicate the above design figures are conservative for pulverized lignite burning. Further, frequent operation of wall type and retractable soot blowers would seem unnecessary. Perhaps a row of wall blowers below, as well as above, the burners would prove an operating aid.

Conclusion

The tests at Aurora completely confirmed previous experiences with lignite. Namely the Bowl Mill will handle high moisture lignite with air temperatures for mill drying of from 550 to 650 F.

Fineness of material leaving the pulverizer need not exceed 70 per cent through the 200-mesh sieve and a fineness of 65 per cent through the 200-mesh sieve is completely adequate.

Tangential firing of lignite is extremely successful as evidenced by the very low carbon loss, excellent ignition stability over a wide load range and overall furnace cleanliness and performance.

Except for the extreme change in Btu per lb of fuel (12,200 down to 6800) and an accompanying inability of the automatic combustion control to perform its function, the change from the Western Kentucky coal to the high moisture Canadian lignite (36 to 38.5 per cent moisture) was made with no deleterious effect on the performance of the equipment.

Equipment performance completely corroborates the earlier $2^1/_2$ years experience established on a horizontally-fired Bowl Mill installation for lignite in North Dakota.

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Carbon-Molybdenum Steel Steam Pipe After 100,000 Hours of Service*

By R. J. SINNOTT and I. A.ROHRIG
The Detroit Edison Company

J. W. FREEMAN and A. I. RUSH
University of Michigan

Rarely does the engineer or metallurgist have an opportunity to evaluate design considerations and laboratory data in terms of creep in service. Carbon-molybdenum steam pipe, carefully measured for service creep during 100,000 hr of operation at 900 F, was subjected to laboratory examination after removal from service. Purpose was to check calculated service creep rates, assess creep damage, and to compare long-time performance prediction based on short-time laboratory data. Remarkable correlation was observed between calculated service creep rates and those established by subsequent laboratory creep testing. Full agreement wih average values used by the Subgroup on Allowable Stresses for Ferrous Materials of the ASME Boiler Code Committee in setting allowable stresses for this material was established for both creep and stress-rupture properties.

When Unit No. 14 was being erected at the Delray Power Plant of The Detroit Edison Company in 1938, the lack of reliable data on service-life properties of metals subjected to high temperatures was felt acutely. The practice of basing design on stresses obtained by 1000-hr high-temperature laboratory tests extrapolated to 100,000 or more hours has repeatedly been questioned. Designers accepted such data only because no better method of property prediction of high-temperature characteristics has been available. It is the purpose of this paper to present (*a*) the results of creep measurements made on carbon-molybdenum pipe subjected to 100,000 hr of actual power-plant service, (*b*) results of after-service laboratory testing, and (*c*) a discussion of service results as compared to properties predicted by laboratory testing prior to service.

Service History

With the installation of Unit No. 14, a service creep-measurement program was initiated. Stainless steel-measuring points were arc-welded on the external surfaces of two 10-in. nominal dia carbon-molybdenum steel pipes connecting the turbine emergency stop valve to the upper and lower steam chests of the turbine. The two Schedule 80 steam leads were designated as "North" and "South" indicating their position with respect to the turbine. The stainless-steel buttons were located to provide both diametral and axial measuring stations and were ground to give accurate measuring surfaces. Fig. 1 illustrates the measuring stations.

Weighted average pressures and temperatures during the operating period are 835 psig and 900 F. Maximum temperature fluctuations of ±20 deg F represent normal operating conditions.

Measurements were made at prevailing temperatures during five outage periods and were taken after the unit had cooled down and the thermal insulation removed from the locations undergoing test. Dimensions were measured with an outside micrometer caliper and a special micrometer trammel. Readings taken were corrected to a base temperature of 68 F. The results of these measurements are shown in Table I.

Plotted service creep calculations based on diametral measurements indicated a typical low stress creep versus time curve over the first 67,000 hr of operation; viz, a relatively rapid initial creep rate followed by a reduction in rate of creep, which is characteristic of material operating under stress conditions producing creep at a low rate. Total diametral elongation at this time was observed to be in the order of 0.1 per cent, a relatively low value. The total axial elongation during the 67,000-hr period as

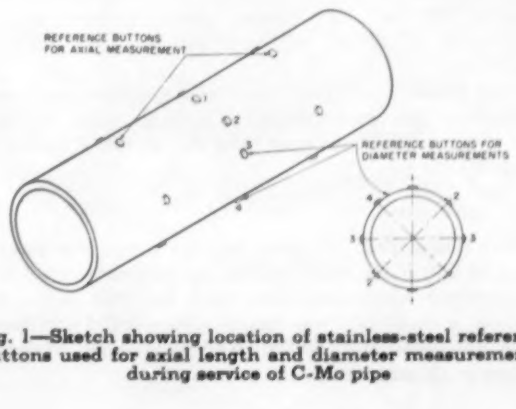

Fig. 1—Sketch showing location of stainless-steel reference buttons used for axial length and diameter measurements during service of C-Mo pipe

* Presented at the Annual Meeting of The American Society of Mechanical Engineers, New York, N. Y., December 2, 1954. Contributed by the Joint ASTM-ASME Committee on Effect of Temperature on Properties of Metals.

determined by axial measurements did not exceed 0.03 per cent and in most cases was considerably less.

After 75,500 hr of operation, weld samples removed from the valve-to-pipe and pipe-to-pipe joints of the South Connection indicated the presence of graphite ranging from dispersed nodular in the valve joint to chain type in the pipe-to-pipe joints. At shutdown intervals during the next 5000 hr of operation, all the welded joints in the turbine leads were first normalized at 1725 F, and shortly thereafter all welds were gouged out, rewelded and normalized. After 100,135 hr of operation, the carbon-molybdenum turbine leads were removed and replaced with chromium-molybdenum pipe, which is highly resistant to graphitization.

Final service creep measurements were made just prior to the removal of the carbon-molybdenum pipe from service. Calculations based on diametral measurements indicated a drastic increase in creep rate over the rate established at the end of the fourth period. Concern over the carbon-molybdenum pipe remaining in service in other portions of the system indicated the advisability of laboratory tests as a check on calculated service creep rates.

Description of Material

The pipe was ASTM A158-36 grade P1, schedule 80, made from National Tube Company's Heat 10043. The reported chemical composition was:

	Per cent
Carbon	0.13
Manganese	0.45
Silicon	0.131–0.135
Molybdenum	0.60–0.62

The pipe was 10.75 in. OD by 0.593 in. wall. After bending and upsetting the ends, it had been given a full anneal at 1900 F for 2 hr. Physical properties were reported as follows:

Tensile strength, psi	60,880
Yield strength, psi	39,730
Elongation in 2 in., per cent	45

Experimental Procedure

Creep Testing

North Connection. Creep tests were run on both tangential and longitudinal specimens at the operating temperature of 900 F and under the estimated operating stress of 7500 psi. In addition, tests were made under the present 12,500-psi allowable stress of the ASME Boiler Code.

South Connection. One tangential specimen and one longitudinal specimen were taken from the pipe. Creep tests of these two specimens were run at 900 F under a stress of 7500 psi.

Rupture Testing

North Connection. A stress-rupture curve was established at 900 F for time periods up to nearly 1800 hr. Longitudinal specimens were used for this test. In addition, a check test was run on a tangential specimen which was tested at 37,000 psi, a stress intended to cause rupture in about 1400 hr.

South Connection. Tests were run on longitudinal and tangential specimens at a stress of 37,000 psi.

Impact Tests

North Connection. Charpy V-notch tests were made on both longitudinal and tangential specimens. Similar tests were made on the pipe material after it had been reheated 2 hr at 1900 F and furnace cooled. All of the Charpy V-notch specimens were tested at 80 F. No impact tests were made on material from the South connection.

Tensile Tests

North Connection. Room-temperature tensile tests were run on longitudinal specimens. No tensile tests were made on material from the South connection.

Hardness Tests

North Connection. Brinell hardness tests were run on eight sections representing the entire circumference of the pipe section.

South Connection. The Brinell hardness was determined on one section representing the South connection.

Metallographic Examination

North Connection. A metallographic examination was made on sections through the center line of the measuring buttons representing the four quadrants of the North connection, and, in addition, samples were taken adjacent to all of the test specimens.

South Connection. Samples were taken at one measuring button and also adjacent to the creep and rupture specimens.

Results

Dimensional Measurements on the North and South Connections

The measurements shown in Table I were made across the diameters of the pipe at the reference buttons. It should be noted that at the time the reference buttons were attached, no attempt was made to keep the height of the measuring buttons uniform. Accurate inside diameter measurement of the pipes was not readily obtainable with the equipment available at the time of installation. Therefore, any initial ellipticity of the pipes which may have existed was not detected, and was not indicated by the diametral measurements made during service. No changes in diameter due to sectioning were observed. The inside diameters were measured at both ends of the pipe ring containing the reference buttons and are recorded also in Table I. Measurements were made on the pipe diameters containing the reference buttons and at diameters between each button. Further, the circumferential length covered by the buttons was determined as a matter of record with the results shown in Table I.

From these data, it was observed that the minimum diameter of the North connection was at the (4-4) axis and at the (1-1) axis of the South connection. These diameters correspond to those showing the greatest increase from creep as judged by the diametral measurements taken during service. Consequently, it must be concluded that the pipes were originally elliptical in shape and were becoming round during service.

The wall-thickness measurements indicated that both

TABLE I—DIAMETRAL MEASUREMENTS OF 10-INCH SCHEDULE 80 CARBON MOLYBDENUM PIPE DURING AND AFTER 100,000 HOURS OF SERVICE

Location	November 1938	August (12,789 Hr) 1940	March (26,937 Hr) 1942	July (43,832 Hr) 1944	June (66,987 Hr) 1947	August (100,135 Hr) 1951	Tot. Change 5 Periods	Cold Relaxed Position After Removal/Line (100,135 Hr)
Diametral Over Stainless Steel Reference Buttons (Inches)*								
North Position								
1–1	11.2876	11.2921	11.2933	11.2948	11.2984	11.3046	+0.0170	11.3052
2–2	11.2756	11.2791	11.2808	11.2818	11.2844	11.2887	+0.0131	11.2912
3–3	11.3161	11.3201	11.3213	11.3218	11.3244	11.3277	+0.0116	11.3292
4–4	11.3536	11.3581	11.3608	11.3608	11.3644	11.3734	+0.0198	11.3740
South Position								
1–1	11.2304	11.2453	11.2512	11.2548	11.2593	11.2945	+0.0641	11.2732
2–2	11.3044	11.3103	11.3137	11.3153	11.3193	11.3305	+0.0261	11.3332
3–3	11.4924	11.4873	11.4852	11.4798	11.4783	11.4785	−0.0139	11.4812
4–4	11.3794	11.3813	11.3812	11.3808	11.3823	11.3865	+0.0071	11.3892

Inside Diameters After Sectioning (Inches)

	1–1	Between 1–2	2–2	Between 2–3	3–3	Between 3–4	4–4	Between 4–1
North connection	9.665	9.666	9.665	9.659	9.666	9.646	9.646	9.657
	9.666	9.654	9.665	9.658	9.661	9.645	9.633	9.653
South connection	9.564	9.575	9.598	9.651	9.683	9.678	9.648	9.612
	9.525	9.539	9.611	9.673	9.697	9.676	9.641	9.583

Circumferential Length Covered by Reference Points (Inches)

North connection—5.090
South connection—5.075

* All measurements corrected to 68 F.

sections varied by a maximum of approximately 0.025 to 0.030 in., a variation which was well within the specified allowances for the size of pipe. However, it should be emphasized that these measurements were made after 100,000 hr of service and that original wall thicknesses were unknown.

Creep Rates During Service

The average rates of creep during service were calculated from the measurements taken on the measuring points during service. The results obtained from such measurements were used to calculate the creep rates by two separate and different approaches; namely, changes in diameter of the pipe, and changes in the perimeter of an ellipse having the dimensions established by the changes in diameter. The latter method is preferred; therefore, the results given for creep during service are based upon changes in the perimeter of an ellipse having the dimensions established by the measurements of the pipe given in Table I. The results of these calculations are given in Table II. Fig. 2 shows graphically the changes in circumference of the pipes as a function of time and service.

The average circumferential creep rates during service show the following:

1. During the first period, the creep rate of both sections was somewhat higher than 0.003 per cent per 1000 hr.

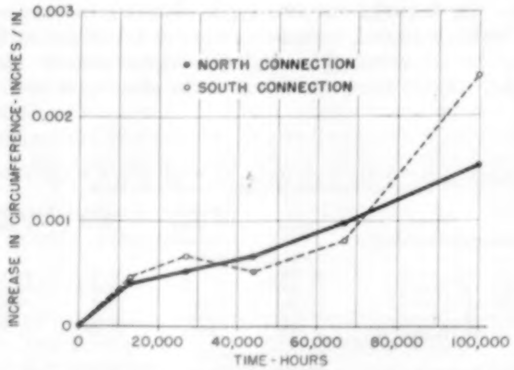

Fig. 2—Change in circumference of 10-in. C-Mo pipe during 100,000 hr of service at 900 F under an operating stress of 7500 psi

2. During the next three periods, the rates were less than 0.0022 per cent per 1000 hr. However, the minimum creep rates were observed for both sections during the third period.

3. During the fifth period, the average rate for the South connection apparently increased to 0.0047 per cent per 1000 hr, whereas the creep rate for the North section was essentially the same as for the second and fourth periods.

It should be emphasized that the measurements made during service reflected very small changes in the diameters as shown by Table I. Consequently, it would not appear that too much significance should be placed on the minor differences in creep rates observed for the different periods: i.e., the low creep rates calculated for the third period of operation. The somewhat higher average creep rates during the first period might have been expected due to the combined effects of primary creep and possible relief of stress concentrations. The apparent increased creep rate of the South connection during the fifth period is clouded by the effects of the removal of the old welds and the rewelding. It does appear highly significant, however, that in general, the creep rates and total deformations, are of the order expected from the extrapolation of laboratory da a.

Tensile and Hardness Properties

Tensile tests conducted at room temperature gave the data shown in Table III. Material from all four quadrants had very uniform tensile strengths and ductility values. Yield strengths and proportional-limit values varied somewhat. There did not, however, appear to be a consistent relationship between specimen location and variation in these values.

Lack of specific comparative data raises the question of

TABLE II—CALCULATED CREEP RATES OF SCHEDULE 80 CARBON-MOLYBDENUM PIPE DURING 100,000 HOURS SERVICE AT 900 F UNDER A NOMINAL STRESS OF 7500 PSI

Period	Duration (Hours)	Accumulated Time (Hours)	Circumferential Creep Rates %/1000 Hours North Connection	South Connection
First	12,789	0 to 12,789	0.00315	0.00365
Second	14,148	12,789 to 26,937	0.00165	0.00220
Third	16,895	26,937 to 43,832	0.00020	−0.0015
Fourth	23,155	43,832 to 66,987	0.00140	0.00130
Fifth	33,148	66,987 to 100,135	0.00165	0.00470*

* Cutting out welds and rewelding may have influenced measurement and creep during the fifth period.

TABLE III—TENSILE PROPERTIES AT ROOM TEMPERATURE FROM THE NORTH CONNECTION C-Mo PIPE AFTER 100,000 HOURS OF SERVICE AT 900 F

Specimen Location	Tensile Strength (Psi)	Yield* Point (Psi)	Proportional Limit (Psi)	Elongation in 1.5 In. (%)	Reduction of Area (%)
2BT	53,000	35,300	27,500	43.3	71.5
2BB	53,400	32,600	—	42.0	71.8
4BT	53,400	32,100	27,000	41.3	71.8
4BB	53,900	38,000	32,500	42.0	71.0

* Specimens showed a very sharp yield point so that this value also is the same as the offset-yield strength values.

whether the low tensile strength was the result of service or if it is characteristic of the somewhat high temperature and slow rate of cooling during the original heat treatment. This heat treatment might be expected to give somewhat lower tensile strength than those usually used for reported data for 0.5 Mo steel. For similar reasons, the yield strengths might have been expected to be low. It, therefore, appears that service may have raised the yield points somewhat as would be expected.

Brinell hardness determinations were as follows:

Connection	Location	Brinell hardness Number
North	Top, side and bottom of pipe	103–107
South	Side of pipe	101

There did not appear to be a significant variation in hardness around the pipe circumference. The hardness values, like the tensile strength, appear to be somewhat low for 0.50 Mo steel. Apparently the hardness was characteristic of the original heat treatment, because reheat treatment at 1900 F for impact testing resulted in a Brinell hardness of 101 to 106. There is, therefore, no real evidence of softening during service.

Impact Properties

Charpy V-notch tests were made at 80 F on specimens taken from the pipes as removed from service and after sections of the pipe had been given the original heat treatment. The data obtained, Table IV, indicate the following:

1. The impact strength ranged from 8 to 11 ft-lb for the pipe material as removed from service.
2. Reheat treatment of the pipe material with the same nominal heat treatment as the original pipe gave an impact strength of 18 to 22.5 ft-lb.
3. The range in impact strengths was too small for any real significance to be attached to the difference in specimens taken longitudinally and tangentially or from the locations of estimated highest and lowest stress concentrations.
4. The influence of prolonged service at 900 F on the impact strength of 0.50 Mo steel is not well established. Such information as is available would indicate that some

TABLE IV—CHARPY V-NOTCH IMPACT PROPERTIES AT 80 F FOR PIPE METAL FROM THE NORTH CONNECTION

As Removed From Service	Impact Strength (Ft-Lb)
Tangential	10, 11
Tangential	7, 8
Longitudinal	11, 9.5
Longitudinal	8, 9
Heated 2 Hours at 1900 F, Furnace Cooled	
Tangential	19, 22.5
Tangential	20, 23
Longitudinal	18, 20.5
Longitudinal	20, 22

Note (1): Specimens were held 16 hours at 200 F after machining. Before testing the specimens were equalized to a temperature of 80 F by holding in a water bath at 80 F.

TABLE V—CREEP TEST DATA AT 900 F FOR 0.50 Mo STEEL PIPE AFTER 100,000 HOURS OF SERVICE

Section	Direction	Stress (Psi)	Creep Rate-%/1000 Hours at Indicated Time: 1000 Hours	2500 Hours
North	Longitudinal	7,500	0.002	—
North	Tangential	7,500	*	—
South	Longitudinal	7,500	0.002	—
South	Tangential	7,500	*	—
North	Longitudinal	12,500	0.012	0.010
North	Tangential	12,500	0.013	0.010

* These specimens showed a decrease in length during the first few hours of testing and no measurable creep thereafter out to 1000 hours.

deterioration would be expected. At least, that is the usual experience in creep-testing. Consequently, it would seem the observed values of 8 to 11 ft-lb do not appear unusual for material with the original heat treatment used for the pipe in question. However, if the pipe had been normalized from 1650 F in place of 1900 F, it is probable that the values would have been higher than 8 to 11 ft-lb.

Laboratory Creep-Test Properties

The creep-rate data obtained from the individual tests are shown in Table V, and the log stress-log creep rate curves derived from the creep-test data are shown in Fig. 3. The curves of Fig. 3 indicate that the stress for a creep rate of 0.01-per cent per 1000 hr was 12,500 psi.

Tests were run at two stress levels:

(*a*) 7500 psi – the stress corresponding to the operating stress during service calculated by The Detroit Edison Company. The measured creep rates ranged from less than 0.001 to 0.002 per cent per 1000 hr. These rates are not considered as precisely established because the sensitivity of the extensometer system, particularly for the 1-in. gage lengths of the tangential specimens, was too low to give exact values. There is no doubt, however, that the creep rates were of the order of 0.001 per cent per 1000 hr.

(*b*) 12,500 psi – the stress corresponding to the present allowable stress under the ASME Boiler Code. Both a longitudinal and a tangential specimen from the North connection gave final secondary creep rates of 0.01 per cent per 1000 hr.

Tangential, as well as longitudinal, specimens were tested because the creep during service was largely circumferential and it was felt that creep characteristics should be established for material with the same orientation as the service creep. The absence of any substantial difference between the two types of specimens appears somewhat unusual, because specimens taken across the direction of metal flow during working usually have slightly higher creep resistance. The absence of specific

TABLE VI—RUPTURE-TEST DATA AT 900 F FOR 0.50 MO STEEL PIPE AFTER 100,000 HOURS OF SERVICE

Specimen Location	Stress (Psi)	Rupture Time (Hours)	Elongation (% in 1.5 In.)	Reduction of Area (%)
North Connection				
2 CB—longitudinal	42,700	S.T.T.T.	38.7	76.8
2 CT—longitudinal	40,000	3.5	44.0	76.2
2 CB—longitudinal	38,000	775	30.0	39.6
2 CT—longitudinal	36,000	1803	21.3	26.2
NA2 B3—tangential	37,000	1482	25.0*	31.4*
South Connection				
SA3 L2—longitudinal	37,000	1558	20.0	26.1
SA3 R1—tangential	37,000	1349	23.0*	29.8*

* Tangential specimens were 0.250 inch in diameter with a 1-inch gage length.

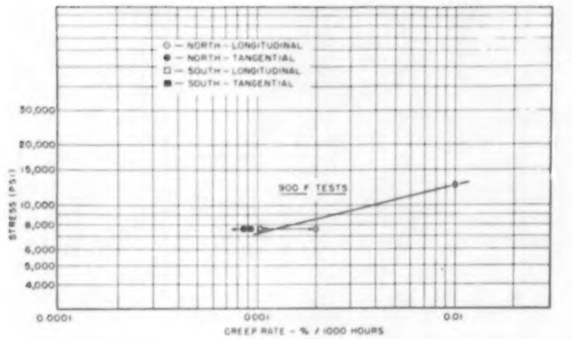

Fig. 3—Stress-creep rate data for 0.5 Mo steel steam pipe after 100,000 hr service at 900 F

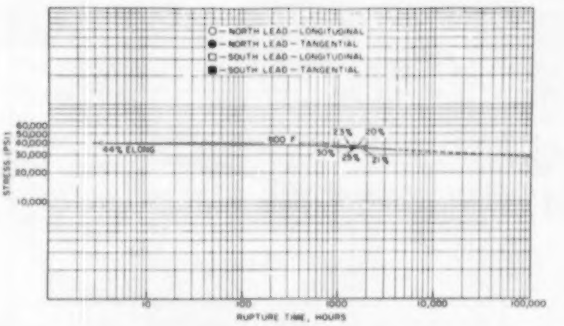

Fig. 4—Stress rupture-time curve for 0.5 steel steam pipe after 100,000 hr service at 900 F

data on this point for pipe produced and heat-treated in the same way as the pipe tested, however, make this uncertain for the particular case.

The tangential specimens tested at 7500 psi showed a decrease in length during the first few hours of testing. The reason for this is uncertain. It could have been due to relief of some complex internal stress system or to testing technique variables. Careful review of the testing procedure showed no reason to believe that it was testing technique.

The 7500-psi tests on specimens from the North and South connections did not show a significent difference in creep rate. The creep rates were so low, however, that it is not certain that some difference in creep resistance did not exist.

Rupture-Test Properties

The data obtained from the rupture tests are given in Table VI and are plotted as the usual log stress-log rupture time curve in Fig. 4. From this curve, the following rupture strengths at 900 F have been estimated:

Stress in psi for rupture in indicated time periods at 900 F

100-hr	1000-hr	10,000-hr	100,000-hr
37,500	37,000	33,000	29,000

The extrapolation to 10,000 and 100,000 hr appears somewhat uncertain in that there seems to be a break in the slope of the stress-rupture curve at about 1000 hr. The tests at longer time periods are insufficient to define the slope of the curve for longer time periods with certainty. The curve has been extended using the greatest slope (lowest strengths) indicated by the available data.

Elongation and reduction-of-area values decreased with rupture time. The short-time elongation was approximately 40 per cent. Tests between 1000 and 2000 hr in duration showed elongations between 30 and 20 per cent. There was no significant difference between longitudinal and tangential specimens or between the two pipe sections.

Metallographic Examination

Test specimens were taken adjacent to or between measuring buttons. The microstructures typical of the test specimens were as follows:

1. The microstructures were ferrite and slightly spheroidized pearlite. In addition, there were apparently fairly massive carbides in the grain boundaries and a light general precipitation throughout the matrix. Scattered graphite nodules were present.

2. The grain size was mainly 5 to 8. No areas of larger grains were observed in the North connection. Occasional nodules of graphite could be found, and it was noted that the massive carbides were absent in the presence of graphite.

3. No significant variations in structure around the circumference of the North connection was observed. The examination of the South connection was less extensive. All samples were, however, similar to the North connection, except for the occurrence of small patches with grain sizes up to grain size No. 3, ASTM Designation E 19.

4. A rather general graphitization was observed on both the inside and outside wall surfaces of both connections. The graphite was quite fine and appeared to be concentrated in the grain boundaries.

The microstructures beneath the stainless-steel buttons had the following characteristics:

1. Segregated graphite approaching "chain" graphite was present under all buttons. In most instances, the chain graphite was either parallel to the surface of the pipe and approximately halfway between the inside wall and the heat affected zone of weld or progressed diagonally in the wall near one end of the button.

2. Only a few isolated nodules of graphite were observed in the heat-affected zone of the welded stainless-steel buttons.

The microstructure of the material reheat treated for impact tests revealed the following:

1. The structure of the reheat-treated material was similar to that of the pipe as removed from service except that there was somewhat less spheroidization of the carbides.

2. The massive carbides observed in the grain boundaries of the pipes also were present in the reheat-treated material.

It was concluded from the metallographic examination that where the metal was not influenced by the stainless-steel measuring buttons, little graphitization had occurred. There also seems to be little question, but that the original carbide lamellae in the pearlite had spheroidized slightly. The presence of what appears to be massive carbides in the grain boundaries was somewhat surprising in view of the relatively slight spheroidization of the pearlite and raises some doubt as to whether they are actually carbides. The slight general precipitation in the matrix was characteristic of 0.50 Mo steel after pro-

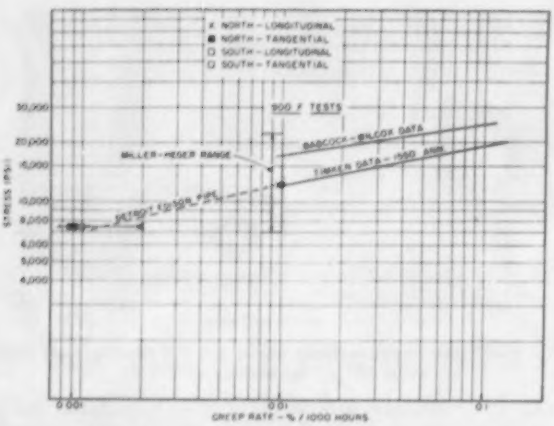

Fig. 5—Creep data at 900 F from C-Mo pipe of Delray Station, Detroit Edison Company, after 100,000 hr of service compared with data for C-Mo steel reported by The Timken Roller Bearing Company (2) and the Babcock & Wilcox Tube Company (1)

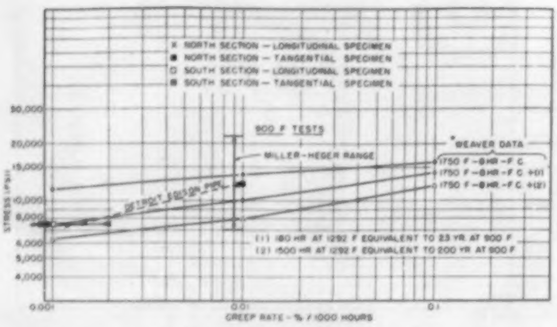

Fig. 6—Creep data at 900 F for C-Mo pipe after 100,000 hr of service compared with data for spheroidized C-Mo steel, as reported by Weaver (4)

longed exposure to stress and temperature. Other than graphitization, the slight spheroidization, "massive carbides" and characteristic general precipitation appear to have been the major structural changes during service. The resistance of the "massive carbides" to removal by heat treatment was interesting and indicates an unusual composition if they are actually carbides.

Discussion

The creep curves, Fig. 2, obtained from the measurements during service are a very unusual set of data. The engineer or metallurgist rarely has an opportunity to evaluate design considerations and laboratory data in terms of actual creep in service.

The exact creep and rupture properties of the particular pipe material at the time it was placed in service were not established. There are, in fact, very few laboratory tests which establish stresses for creep rates as low as those measured in service (less than 0.002 per cent per 1000 hr, Table II). Creep strengths of C-Mo steel are rather variable, depending on heat treatment and melting practice. The exact creep rate for the service stress of 7500 psi at 900 F is therefore not well established. Extrapolation of the available laboratory creep data at higher stresses back to 7500 psi, however, suggests that on an average, rates of the order of 0.001 per cent per 1000 hr might be expected (see Fig. 5). The observed creep in service, therefore, is considered to be in good agreement with the predictions of laboratory data.

The creep rates measured in service and those measured in the laboratory for tests at 7500 psi on coupons cut from the pipes after they were removed from service are in good agreement. This confirms the service creep measurements. It would be expected that, after a brief period of adjustment, the two creep rates ought to agree.

The stress for a creep rate of 0.01 per cent per 1000 hr established in the laboratory, 12,500 psi, and the stress for rupture hours, 29,000 psi, turned out to be in exact agreement with average values for new steel. The observed creep strength is the average value found by Miller and Heger (3) and used by the Subgroup on Allowable Stresses for Ferrous Materials of the ASME Boiler Code Committee in setting the present allowable stress of 12,500 psi. The same group also developed an average value for rupture strength of 29,000 psi.

The average values for strength of the pipe material after prolonged service may appear to be somewhat surprising. Actually, however, this is to be expected if it is assumed that the pipe metal had nearly average properties initially. It is generally considered that exposure to stress and temperature will permanently use up the available life of metals by creep. Consideration of the service conditions, however, indicates that this should have been very small. If the stress-rupture time curve of Fig. 4 was extrapolated to 7500 psi, the indicated rupture time would be many millions of hours. On this basis, 100,000 hr of service was negligible in comparison to the total life available. Certainly the percentage of life used on this basis was too small to alter significantly the rupture-test results.

The laboratory creep data show no evidence of weakening from the 100,000 hr of service. As previously discussed, the creep rates were the same as those existing during service. Creep rates from laboratory tests, however, would be expected to show evidence of structural deterioration only if so-called third-stage creep had started during service. There is no precedent of which the authors are aware for estimating when third-stage creep should become evident in such prolonged time periods and at such low creep rates as existed in service. General laboratory experience indicates that, in the absence of substantial loss of strength by structural alteration due to temperature, third-stage creep would not be expected before the total creep deformation reached 1 per cent. The creep deformation during service, Fig. 2, was of the order of 0.2 per cent and the probability is that the onset of third-stage creep was remote. The test results support this view. The rates observed were average for the steel and there was no indication of increasing creep rates during the tests or in service at either 7500 or 12,500 psi.

The possibility exists that structural alteration under the influence of temperature and stress during the prolonged service could have altered substantially the creep properties from those characteristic of the new pipe. Unfortunately creep data for the particular pipe samples before service are not available. The data obtained from the tests on the pipe after service are compared in Fig. 6 with those presented by Weaver (4) in which he

attempted to estimate the effect of spheroidization during service. At 0.01 per cent per 1000 hr, the creep strength was in between that for the annealed condition and for a condition of spheroidization equivalent to 23 years of service at 900 F. Actually the strength indicated is almost exactly that which would be estimated from Weaver's data. The 100,000 hr of service represents about one-half the 23 years estimated by Weaver to attain the degree of spheroidization of his test bars and the creep strength of the pipe material is also about halfway between his two conditions. The microstructure also showed about the degree of spheroidization consistent with the creep strength in comparison to Weaver's data.

The creep strength of the pipe at 7500 psi in both service and laboratory tests did not agree as well with Weaver's data. Both showed a stress for a creep rate of 0.001 per cent per 1000 hr of about 7500 psi or a little less. This corresponded to Weaver's material spheroidized for an equivalent of 23 years of service, rather than to his annealed stock, which showed a stress of 11,600 psi for 0.001 per cent per 1000 hr. Because the pipe showed creep rates from early in its service life of the order of 0.001 per cent per 1000 hr, the indications are that the pipe material had different stress-creep rate relations than Weaver's test stock. Weaver annealed his stock from a lower temperature than was used for the Detroit Edison pipe. White and Crocker (5) reported creep data at 925 F for C-Mo pipe given the same heat treatment but from different heats as the pipe used for the service creep tests. Extrapolation of their data to 900 F indicated strengths of 11,000 and 12,500 psi for 0.01 per cent per 1000 hr. In view of such variation, there seems sufficient precedent to assume that the service creep data reflect initial properties more than changes during service.

Similarity of Properties

The similarity of creep and rupture properties of tangential and longitudinal specimens indicated that there was no great difference from this source in the properties of the pipe after service. Because creep in service was circumferential, it could be expected that any damage effect might be most evident in the tangential specimens. The absence of any difference between the longitudinal and circumferential specimens then could be further support to the indication that the 100,000 hr of creep in service had used up only a small fraction of the available service life of the pipe. Without supporting data on the probable relative strengths of longitudinal and tangential specimens for new pipe or for pipe subjected to creep, there is uncertainty in these conclusions.

The elongation and reduction-of-area values for the rupture-test specimens were not as low as have been observed for C-Mo steel. The change from 40 to 20 per cent elongation as the time for fracture increased to 2000 hr is not at all unusual. Certainly there is nothing in these values to suggest undue deterioration during the 100,000 hr of service.

The impact values after service were low. However, impact values of 10 ft-lb are not at all unusual for C-Mo steel, particularly when heat-treated at a relatively high temperature, as was the pipe. The difference in relation to the samples reheat-treated after service does not represent an unexpected change. The absence of any difference between longitudinal and tangential specimens again supports the view that creep damage during service was very slight.

The tensile properties after service possibly show some evidence of structural change during service. There is some uncertainty in this observation, because the comparative data for new material are inadequate. In either event, the properties were satisfactory and the changes were no more than might be expected for 100,000 hr of exposure to 900 F under stress.

Summary and Conclusions

A unique set of creep curves is presented for the creep of two C-Mo steel steam pipes during 100,000 hr of service at 900 F. Analysis of the data shows that the observed creep rates of 0.002 per cent per 1000 hr or less under an operating stress of 7500 psi were in accordance with the predictions of laboratory creep data.

Laboratory creep and rupture tests were carried out on coupons cut from the pipe after the 100,000 hr of service. The creep rates under 7500 psi agreed with the rates observed in service. The creep strength of 12,500 psi for a rate of 0.01 per cent per 1000 hr and the stress for rupture in 100,000 hr of 29,000 psi are the same as the average values for new C-Mo steel.

Analysis of the service conditions indicated that 100,000 hr of service at 900 F under 7500 psi would have been expected to use up only a negligible amount of the available creep-rupture life of the steel. All laboratory test results support this conclusion. Deterioration of creep strength due to structural changes, such as spheroidization, was certainly no greater than might have been expected.

The general conclusion is that the pipes performed in service to a remarkable degree in accordance with the predictions of laboratory data.

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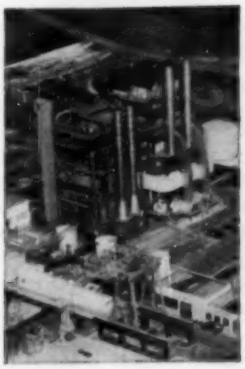
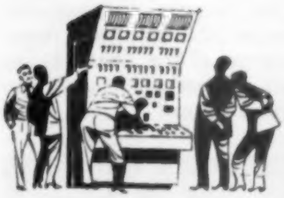


Louisiana Power & Light Company's third unit at Ninemile Point Plant designed by Ebasco Services, Incorporated with Instrumentation and Control by Hays.



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ASME Annual Meeting in Review

Continuing its trend toward more simultaneous sessions and a greater number of papers on an ever widening variety of subjects, The American Society of Mechanical Engineers held its 1954 Annual Meeting at the Hotels Statler, McAlpin and Governor Clinton on November 28–December 3. More than 7000 mechanical engineers participated in the 124 technical sessions and heard a total of almost 350 papers. To keep this report to manageable length only those papers believed to be of direct interest to the power industry will be reviewed. Abstracts of additional papers on heat transfer, flow in pipe, metal properties and instruments will appear in January COMBUSTION.

David W. R. Morgan of Westinghouse Electric Corp. was elected president of the Society, succeeding Lewis K. Sillcox of the New York Air Brake Co.

At the president's luncheon, Dr. Sillcox joined with Harry R. Westcott, president of Westcott and Mapes, Inc., in honoring Ernest Hartford, deputy secretary of the ASME staff. Mr Hartford, after 43 years of widely acclaimed service, is retiring although he will continue to serve the Society in a consulting capacity. In an

Harry R. Westcott presenting to Ernest Hartford a bound volume of more than 200 letters entitled "The Tribute of His Friends"

address entitled "Pathways of Progress" Dr. Sillcox cautioned that progress in science must be matched by progress in humanities. What we need is an integration of engineering progress with humanistic goals. No society is any bigger than its leadership, and mankind's progress is intimately connected with individual progress in terms of peace of mind and idealistic aspirations.

Fifteen hundred engineers and their guests heard Dr. John R. Dunning, Dean of Engineering at Columbia University, address the annual banquet on the subject "Engineering Comes of Age." He contended that no matter what may transpire in the next fifteen years it will be necessary to maintain and increase our technological strength. Russia makes scientific technology the basis for running the country. To keep pace the United States must achieve the same emphasis by improving the training of our technicians all along the line. We must show more concern with the rate at which Russia is building up its scientific and engineering strength. Dean Dunning also called for a return of engineers to positions of prominence in political life, observing that there are fewer engineers in Congress today than was the case in the days following the Revolutionary War.

At the banquet honorary membership in ASME, the highest honor granted by the Society, was conferred on two outstanding engineers well known in the power field: Henry B. Oatley, chairman of the ASME Boiler Code Committee and former vice president and consulting engineer with The Superheater Co.; and A. L.

C. E. Davies, secretary of ASME; L. K. Sillcox, retiring president; D. W. R. Morgan, incoming president; F. S. Blackall, jr., past president

Penniman, vice president of Consolidated Gas Electric Light & Power Co. of Baltimore, Md. The ASME medal was awarded to E. B. Powell, for many years consulting engineer with Stone & Webster Engineering Corp., while Walker L. Cisler, president of Detroit Edison Co., received the George Westinghouse gold medal award. Two Worcester Reed Warner medals, which recognize outstanding contributions to permanent engineering literature, were presented. The 1953 Warner medal was awarded to Prof. William H. McAdams of M.I.T. for his valued reference book and text entitled "Heat Transmission," while the 1954 medal went to Prof. Joseph H. Keenan of M.I.T. for his authoritative volume on "Thermodynamics."

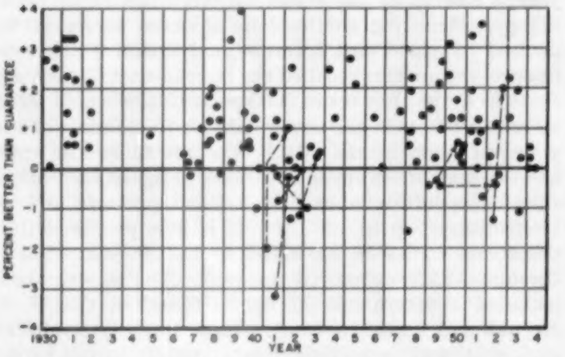
Announcement was made by the Nuclear Energy Application Committee that the Nuclear Engineering Committee was raised to divisional status. A. C. Pasini of Detroit Edison Co. is acting as chairman.

Plans were announced for the celebration of the 75th anniversary of the founding of ASME. Special anniversary meetings to commemorate the founding and organization of the Society will be held on February 16 and April 16, 1955.

Steam Turbine Testing and Design

Engineers of the General Electric Co. presented two papers on turbine testing, one dealing with field testing of large steam turbine-generators in the owner's plant and the other on tests of medium-sized units, most of which were conducted in the manufacturing plant at Lynn, Mass.

E. M. Kratz, in a paper entitled "Experience in Testing Large Steam Turbine-Generators in Central Stations," pointed out that experience has shown that consistent results can be obtained only by providing carefully calibrated instruments used carefully and with adequate knowledge of possible sources of error. Since 1930 General Electric has tested 111 turbine-generators of 15,000 kw or larger, 102 of which were single-shaft machines and the remainder cross-compound units. Reheat was incorporated in the design of 12 machines, and 18 of the tests were on non-condensing turbines. Mr. Kratz presented a chart showing the test results in terms of guaranteed values and other curves which indicated



Test results on turbine generators 15,000 kw and larger based on average of $^1/_2$, $^3/_4$ and full load

consistency in results on the basis of comparison of heat rates. With respect to accuracy, throttle flow measurements are the most frequent source of inaccurate data because of the difficulty in obtaining a precise basic measurement and the additional possible sources of error from miscellaneous flows and inadequate isolation. Generator load measurements may also be the source of significant errors, though of a smaller magnitude.

"Accuracy and Results of Steam Consumption Tests on Medium Steam Turbine-Generator Sets" by **D. E. Kimball** was a report on tests of 22 units rated 2500 to 18,750 kw. These tests were conducted between 1946 and 1952 on facilities for loads up to 15,000 kw with steam conditions as high as 1500 psig, 1000 F. In analyzing the accuracy of the tests that author shows the existence of (1) 0.5 per cent uncertainty in manufacturing and factory-testing, (2) 0.3 per cent as the day-to-day uncertainty of tests, (3) 0.17 per cent uncertainty to be charged to the instrumentation of factory tests, (4) probably 0.5 per cent poorer performance of tests in the owner's plants than in factory tests. Certain precautions were taken in conducting the tests, including testing five sets of duplicate turbines, measuring most data on two or more identical instruments duplicating each other, retesting runs on the same turbine and making certain that similar design and manufacturing as well as inspection practices applied both to the tested and untested turbines.

Charles D. Wilson of Allis-Chalmers Manufacturing Co. presented a paper entitled "Close-Coupled Cross-Compound Arrangement for Compact Large Capability Steam-Turbine-Generator Units." He pointed out that the characteristics of this type make it ideally suited for generating units of large capability and mentioned some of the considerations in designing a 325,000-kw unit. With the 1800-rpm low-pressure turbine it is possible to provide the optimum size of exhaust blading that is required for the efficient performance of a large machine. Because of the use of two generators it is possible to build units of very large capability with moderate-sized generators. With exhaust pressures of 1 in. Hg or less the cross-compound machine is attractive for ratings of 150,000 kw and larger, while at exhaust pressures of $1^1/_2$ in. it can be applied to ratings of 200,000 kw and larger. Floor space requirements have been greatly reduced by the new close-coupled arrangement where both the high- and low-speed elements are mounted close together on a common foundation. This greatly reduces the length by comparison to a tandem-compound machine and permits either transverse or longitudinal installation with minimum crane span.

In a paper entitled "Considerations in the Mechanical Design of High-Temperature Steam Turbines," **W. E. Trumpler, Jr.** and **E. A. Fox** of Westinghouse Electric Corp. stated that far more is required in turbine design practice than mere substitution of numbers into formulas. Pure mathematical extrapolation of creep-test data must be tempered by judgment based on experience with materials involved and an understanding of service requirements. When considering designs involving creep-type plastic flow, components must be considered to have a finite life. Such factors as initial cost, downtime for replacement or maintenance and thermal efficiency must be taken into account in determining the life for which each component must be designed for central station service. Increased activity must be encouraged in high-temperature testing programs to obtain more long-time creep rate and creep-to-rupture information, particularly on the newer austenitic super-alloys. This work must include further study of behavior under the effect of biaxial and triaxial stress situations. More reliable means of judging materials from short-time creep data must be devised.

Central Station Boilers

Under the sponsorship of the Power Division a series of four papers was presented under the general subject of boiler developments. In the first of these under the title of "Superheater Metal Temperature," **G. Parmakian** and **N. S. Sellers** of Riley Stoker Corp. outlined a detailed design procedure for evaluating the several variables involved in the determination of wall temperature of superheater and reheater tubing. They pointed out that the designer attempts to keep metal temperature as close as possible to steam temperature. Among the methods employed are (1) use of high steam mass flows,

(2) selection of small tube diameters, (3) use of relatively low gas mass flows in high-temperature superheater sections, (4) liberal design of the manifold system and (5) achievement of good gas temperature and flow distribution through furnace and burner design. The authors also discussed at some length actual temperature distribution, including metal-temperature unbalance and effect of burners, and made recommendations for using thermcouples to measure and record metal temperatures of superheaters as an aid to operation.

"Principles of Boiler Design for High Steam Temperatures" by **G. W. Kessler** of the Babcock & Wilcox Co. indicated some of the ways to achieve higher thermal cycle efficiencies and the effect of improvement in heat cycle on boiler design. Much of the paper was concerned with methods of maintaining steam temperature, including variation in furnace heat absorption, the use of radiant superheaters and reheaters and applications of gas recirculation. Mr. Kessler concluded that the major obstacle in the advance to higher steam temperatures is the restriction necessarily placed on furnace exit gas temperatures to assure cleanliness of the convection surfaces. The advance to higher steam temperatures will depend primarily upon overall economics, and material development and possible better material usage will be major factors in future advancement.

E. M. Powell and **H. A. Grabowksi of** Combustion Engineering, Inc., in a paper entitled "Drum Internals and High Pressure Boiler Design," pointed out some of the factors which affect separation of water from steam in high-pressure boilers. These include the relative densities of water and steam, available pressure drop for drum internal design, relative quantity of water to steam in the mixture delivered to the drum, total throughput requiring separation, boiler water level and concentration of boiler water solids. They provided a comparison of available head in a 110-ft high furnace having a circulation ratio of four pounds of water per pound of steam generated. At 1600 psig this head amount to 10 to 12 psig, whereas under the same conditions at 2400 psig it falls off to 4 psig. Another section of the paper took up steam purity testing and provided results obtained in four controlled-circulation boilers having drum pressures ranging from 2650 to 1775 psig and boiler water concentrations between 100 and 400 ppm. For the conditions tested with turbo separators installed in the drums, solids in the steam varied from 0.04 to 0.08 ppm. Several charts were presented to show drum metal temperature distribution and the effect of controlled circulation in insuring uniform heating rate for rapid starting of boilers.

Developments extending over a period of 35 years were outlined by **H. H. Hemenway** of Foster Wheeler Corp. in a paper entitled "Radiant Superheater Design and Experience." Since the first radiant superheater was installed in 1917 more than 1000 have been placed in service in boilers of many types ranging from box-header and two drum low-head units for marine service to large central station installations, of which the Port Washington and Oak Creek Stations of Wisconsin Electric Power Co. are examples. Mr. Hemenway explained some of the changes in material specification and manufacturing techniques that have occurred as the result of experience with radiant superheaters and reheaters. Performance characteristics have been remarkably good, especially in the case of combination radiation-convection surfaces because of their compensating steam-temperature characteristics. In concluding the author stressed that modern thinking in the electric power industry indicates a trend toward greater conservatism in design and that radiant steam-cooled surfaces have an important part to play in this trend.

Steam Tables

The ASME Research Planning Committee sponsored a session at which two papers on steam properties were presented to illustrate the type of research in this area now planned under the auspices of the Society. The first of these, "The Present Status of Steam Properties," was prepared by **Prof. Frederick G. Keyes** and **Prof. Joseph Keenan** of the Massachusetts Institute of Technology. Referring to the 1934 skeleton steam tables devised by the Third International Steam Table conference, the authors recalled the hope of that Conference that the limits then set of 5000 psia, 1032 F would serve all requirements in the power field for the lifetime of the youngest participants. Such was not to be the case, as evidenced by projects now being designed for central stations operating above the critical pressure and at temperatures up to 1200 F. It is now proposed that the steam tables be extended to 15,000 psia, 1500 F through ASME-sponsored research. The paper, which included a comparison of values found in the U. S. Keenan and Keyes tables and those recently published in Russia, will be published substantially in full in the January 1955 issue of COMBUSTION.

In a companion paper, "Thermodynamic Properties of Steam at Elevated Pressures and Temperatures," **Henry Hidalgo,** formerly of the Research Department of the United Aircraft Corp. in East Hartford, Conn., and **Roy Nutt** of the same organization supplemented the data of present Keenan and Keyes steam tables in the regions 5500 to 10,000 psia and 800 to 1600 F. A modification of the Keyes equation of state was made by using the conditions that this modification should yield pressure-volume-temperature data that satisfies (1) the experimental data of Prof. G. C. Kennedy of Harvard University at the upper pressure limit of the region of interest; (2) the upper pressure region of the steam tables data; and (3) the approximate magnitude with the proper algebraic sign of both the second derivatives of the isometrics in the pressure-temperature plane and of the first derivatives of the reduced isothermal lines in the generalized plane. The equation of state thus obtained was numerically integrated for the determination of enthalpy and entropy. These integrations, as well as the determination of state, were made with the aid of the 701 IBM computing machine. The authors also compared the data thus obtained with the Russian data and found discrepancies of the same order as exist with respect to the comparison of the Keenan and Keyes and Russian tables.

Boiler Feedwater Studies

There were two sessions presented by the Joint Research Committee on Boiler Feedwater Studies with the major emphasis on corrosion problems and their correction. The first of the two sessions was a symposium on chemical deaeration and corrosion control to evaluate certain treatment chemicals.

S. T. Powell and **L. G. von Lossberg,** of the S. T. Powell Consulting Chemical Engineers, led off at the opening session. They prefaced their paper by a statement explaining that the paper was limited to conditioning chemicals that were (*a*) reagents primarily for deoxygenation or (*b*) miscellaneous inorganic and organic materials for minimizing corrosive attacks on metals.

Realization of the need for removal of the noncondensable gases in feedwater brought on the development of deaerators, deaerating hot wells of surface condensers and supplementary chemical treatments for scavenger duty. Sodium sulfite for years performed the scavenging requirement. Lately there have been claims that sulfite has created certain difficulties in the system and while there may be some justification in individual cases most difficulties are due to inadequate control. For example recorded data show that in boilers operating at 1000 psi and a boiler water pH of about 11.0 sodium sulfite concentration should be held below 10.0 ppm. Boilers operating from 1200 to 2000 psi require maintaining sodium sulfite concentrations to not over 5 ppm.

Sulfite of other chemically-treated feedwater for desuperheating or attemperating to control final steam temperature can, in the authors' opinion, be used with no adverse results. It requires, though, that the water cycle contain a relatively satisfactory mechanical deaeration arrangement, and that deoxygenating chemicals be employed to remove traces of oxygen.

Hydrazine has been employed in some cases to get around the limitations cited for sodium sulfite. It has an especial appeal for station operators that have abandoned sodium sulfite or want an oxygen-free water for desuperheating without the addition of solids to the system. But there are certain precautions that must be met. For example anhydrous hydrazine is a dangerous material and should not be employed for power plant service. Hydrazine hydrate as a 35 per cent solution, however, does very well. It can be handled with no greater safety provisions than those used for dilute acid and ammonia. The quantities employed must be closely watched since some report excessive generation of ammonia. Later findings, though, indicate excessively high concentrations were maintained.

The use of volatile alkaline amines to increase the pH of the condensate has gained considerable popularity in recent years. Morpholine seems favored for pH and corrosion control in the steam-water cycle because it is said to have a more satisfactory ratio of distribution between vapor and liquid phases than ammonia or some other amines used for this purpose. Waxy amines seem to give favorable results in low-pressure steam-generating systems.

R. C. Harshmann and **E. R. Woodward,** Olin Mathieson Chemical Corp., fashioned their paper, "Hydrazine for Boiler Feedwater Treatment," around the particular properties of hydrazine that make it useful for boiler feedwater treatment. High among these properties are the following. Hydrazine is a strong reducing agent, reacting readily with oxygen, is commercially available in solution and is completely miscible with water. It is a more effective reducing agent in alkaline solutions, being most effective in the range of preferred boiler operation. Of particular interest is the fact that hydrazine itself and its decomposition and reaction products do not contribute to the solids content of the boiler or give acidic reactions.

The authors traced the reactions of hydrazine in removing residual oxygen in a feedwater. They then discussed methods of application, and safe ways of handling and concluded with a referral to the fact that hydrazine was now in use on several central station boilers in this country with new users in the preparation stage.

J. Leicester, head of the Chemical Engineering Div., Admiralty Materials Laboratory, England, handled "The Chemical Deaeration of Boiler Water—The Use of Hydrazine Compounds." He began with the major reaction equations of hydrazine both with residual oxygen in water and its own decomposition products. Experiments have been carried out in England on the oxygen/hydrazine reaction and considerable work is now in progress in a pilot-plant high pressure boiler at the Admiralty Materials Laboratory. This work, it is hoped, will be correlated with the results of full scale boiler trials now in progress throughout Great Britain.

One vital way of studying and understanding the oxygen/hydrazine reaction was held by Mr. Leicester to be a fundamental study of the kinetics of the system. A Mr. C. Moreland, Birmingham, England, now has such a study underway and is particularly studying the effects of hydrazine concentration, temperature and pH of the water. An investigation is also looking into the effect on reaction rate of metal catalysts, either in the form of a suspension or present as solid surface. This investigation will be published in the near future.

At the moment the most important conclusion from these initial experiments is that even in dilute solutions and at low temperatures the hydrazine/oxygen reaction can proceed as a surface reaction. The author felt that oxide films formed on the surface of a solid or on suspended particles in the solution provided the necessary step for the hydrazine reaction.

An independent series of small-scale experiments is being carried out in the British Launderer's Research Assn. laboratories with a stainless steel autoclave at pressures of 500, 750 and 1000 psig. Both idle and steaming conditions are under investigation with hydrazine-hydrate and also dehydrazine phosphate concentrations of theoretical, 100 and 200 per cent excess strength. At present these tests have only gone as far as reaction rates of the hydrazine-hydrate in cold solutions. The Moreland tests mentioned above show considerably slower reaction rates under cold solution conditions than do the series at the Launderer's Laboratory. The Moreland experiment, though, employs only glass apparatus and the Launderer's uses metal surfaces which give a metal area considerably greater per unit volume of water than in any other cases on record including full-scale boiler trials.

The Admiralty Materials Laboratory is running the same experiments as the Launderer's Laboratory in a boiler system where there is circulation as against the non-circulating situation within the Launderer's auto-

clave. The system selected was a pilot-plant high pressure boiler where an attempt will also be made to obtain an overall material balance for the boiler and the feedwater systems. From the present, as yet inconclusive trials, it appears that a residual hydrazine content of 0.25 to 0.30 ppm can be tolerated in a steaming boiler before decomposition to ammonia occurs.

J. D. Rostroph, Virginia Electric and Power Co. and **E. A. Yorkgitis,** Hall Laboratories, selected as their topic, "Controlling Iron and Copper Pickup With Neutralizing Amines." They prefaced their report with the statement that central stations carrying out effective deaeration and employing scavengers to keep oxygen concentrations at a minimum find iron and copper pickup to be greater in general at lower pH values. They have two types of inhibitors they can use to restrict this corrosion—a volatile, alkaline substance to raise the pH or a volatile, filming substance to lay down a protective film to separate the metal from aggressive condensate. The volatile alkaline to raise pH was the method covered in this paper.

Cyclohexylamine and morpholine were fed to the steam-feedwater cycle of a high pressure, reheat, controlled-circulation boiler. During treatment with either amine, average iron and copper concentrations throughout the system were less than 0.01 ppm. Within the accuracy of the meter the pH stayed practically constant throughout the sytem with both amines, except in the after-condenser drains. Here cyclohexylamine displayed less constancy after the 17th stageheater.

The pH dropped from 9.09 to 9.01 in passing through the 14th stage deaerating heater with cyclohexylamine and went back up to 9.12 between the 14th stage and the economizer which lies on either side of where the amine is fed into the system. Yet there was no comparable increase between these points when morpholine was fed at the same place. Whatever cyclohexylamine is lost at the deaerator is offset with morpholine losses in the blowdown since feed rates to maintain pH remained closely comparable.

Certain tests indicated that morpholine addition results in more ammonia breakdown than does the cyclohexylamine but this difference might be traced to the almost double concentration of morpholine to hold the same system pH of 9.0–9.1.

Sampling and analytical procedures employed by the authors were furnished as an appendix to the paper.

Air Pollution and Dust Collectors

As might be expected a number of different sponsors presented papers in the general field of air pollution control and dust collector development. There were sessions put on by the Fuels and Power divisions and the Air Pollution Controls Committee.

H. J. Scott, commissioner of air pollution control, Cleveland, advanced the thinking of at least one municipality in establishing the background for control of air pollution. Mr. Scott described how Cleveland recognized there were industrial effluents not within the scope of smoke abatement. Accordingly the city set up a separate bureau for this problem.

That bureau initiated in 1949 a program to evaluate the concentrations of pollutants with particular respect to weather. Through the united efforts of this city bureau, fourteen major industries and the United States Weather Bureau the relationships between air pollution and meteorological factors have been and still are being studied. Sampling stations were established in an industrial area and simultaneously operated for extended periods over a three-year duration.

This group adopted standard equipment and sampling methods, recorded air pollution and meteorological factors and statistically analyzed these data as to the relationships between air pollution and certain of these factors. A method of forecasting the amount of air pollution was presented. The method involves (1) a table or chart showing the main concentration with each wind direction, (2) correction factors for diurnal variations, (3) correction factors for the influence of inversions, (4) on accurate wind direction forecast and (5) a forecast of the time of occurrence and duration of inversions.

F. T. Bodurtha, Jr., E. I. du Pont de Nemours & Co., produced a second paper along the same lines entitled "A Technique for the Rapid Solution of an Air Pollution Equation." The approach Mr. Bodurtha employed was largely mathematical. He began with the premise that it is necessary to provide means of keeping the ground level concentration of effluent gases below specified values. Stacks are commonly used for this purpose. Necessary stack heights for single sources may be calculated from formulas developed by Bosanquet and Pearson and Sutton. A reference was made to an earlier comprehensive discussion on the application of these formulas in Chapter 8 of the Manufacturing Chemists Assn. publication *Air Pollution Abatement Manual.*

Methods for rapid solution of the Bosanquet and Pearson formula were developed for use with stack gases at or near atmospheric density. But the author cautioned that the present knowledge of atmospheric turbulence is greatly limited. Hence these equations apply with appropriately limited accuracy. But even with these restrictions the equations should help solve certain air polution problems.

E. W. Hewson, professor of meteorology, University of Michigan, added still more to the thinking of the above papers. He combined aerodynamic and meteorological concepts in a procedure for estimating ground concentrations of effluents from stacks with various heights and exit velocities in a paper entitled, "Stack Heights Required to Minimized Ground Concentrations."

Professor Hewson employed the reasoning that the atmosphere is a vast reservoir which may be used for the disposal of industrial wastes. If sensibly used for this purpose no nuisance or damage is incurred. But without due consideration of its widely varying diffusion capacity, annoyance, illness or even death could conceivably result from discharging wastes into the air. The basic influences at work are described by the author as background information for understanding the detailed method he employed in computing ground concentrations.

The author frequently referred to earlier work by Sherlock and Lesher and, in fact, employed wind tunnel data from their experiments to develop his computation procedure. Then with a hypothetical case Professor Hewson worked through the computations involved in his method.

"The Mechanism of Separation in the Louver-Type Separator" was the subject chosen by **J. L. Smith,** U. S. Army, and **M. J. Goglia,** Georgia Institute of Technology, on the contention that very little is known about the mechanism which separates dust particles from a gas stream in a louver separator. All the understanding seemed to be that it is easier for air to negotiate a sharp turn than it is for high inertia dust.

A system developed during the study of this mechanism and suggested by the Tindall meter made it possible to follow the particle paths by reflected light. Accordingly a preliminary study of the particle paths in a two-dimensional louver separator was conducted to bring out the effectiveness of the separator on different particle sizes. The air flow pattern was found to be the controlling factor and hence the shape of the housing on both sides of the louver is of the utmost importance.

From the particle path studies it was concluded that an effective louver blade shape separates the region of particle impacts with the blade from the region where the air is passing between the blades. The particle size studies showed the separator was effective down to 10 micron sizes but was more effective for particles above 10 microns. The data showed the per cent of the initial dust separated was essentially independent of the initial air velocity and initial dust concentration.

Several papers were delivered on the general subject of dust collectors and their design and performance. **Carl R. Flodin** and **Harold H. Haaland,** Western Precipitation Corp., commented on "Some Factors Affecting Fly-ash Collector Performance in Large Pulverized Fuel Fired Boilers." For many years fly-ash collection from pulverized units was not considered a particularly difficult problem since expected collection efficiencies were low (80 to 90 per cent) and the character of the ash such that high efficiency cyclonic collectors or electrostatic precipitators could satisfactorily meet the requirements. As an example precipitators for this service ran one-half to one-quarter the size regularly used for cement and metallurgical operations for equivalent gas volumes and efficiencies.

But today demands call for higher efficiencies and low stack emissions so that it is necessary to regard the collection equipment as a part of the furnace and to obtain peak performance at all times. Yet in the face of this demand design factors for certain stations are working against the collector. The authors discussed the major factors in dust collector design both cyclonic and precipitator and in operations that bear upon an overall evaluation of collector problems.

A. J. Tigges, Jackson & Moreland, and **Hilmer Karlsson,** Air Preheater Corp., joined forces to present the paper "Lower Flue Gas Exit Temperatures Through Removal of the Solids Ahead of the Air Preheater." This paper traced the reasoning behind a detailed research program for increasing overall boiler efficiency by reducing gas exit temperatures and yet maintaining the necessary high availability required by modern central station practice. To achieve this seemingly contradictory goal required some solution for the corrosion and deposit problem which appeared in the path of the exit furnace gases.

There were three contributing factors all of which had to be present at the same time to cause deposits and later corrosion. They were, first, sulfur compounds in the fuel which at the present state of the art could not be removed economically. Next was the factor of water vapor always present in all boiler flue gases and not removable before it can cause trouble. Third and last, the very finely divided particles of fly ash which must be present for deposit and corrosion to occur. This last factor seemed to lend itself to further control than was the case in present-day boiler practice. The flue gas borne solids had to be removed, the authors felt, before they could become wet and adhesive, or in other words, in a dry state.

Particles in the size range of ten microns and down are responsible for causing visible stack discharges as well as deposit and corrosion problems on the low temperature surfaces. This fly ash is hygroscopic, can adsorb water vapors and gases at relatively high temperature, and is particularly pronounced in the case of fines which can raise dewpoint temperatures as much as 75 F. High sulfur fuel oil indicates this phenomenon at temperatures over 350 F.

These theories were put to the test at three sites, a prototype dust collector installed on a small test set at Waltham, Mass., and experimental installation at the Hell Gate Station of Consolidated Edison Co., and a full scale application at the Barking Steam Generating Station, east of London, England.

H. Klemperer, Air Preheater Corp., and **J. E. Sayers,** James Howden & Co., Ltd., described in their paper "Design Aspects of an Electrostatic Precipitator for the Collection of Small Solids Ahead of the Air Heater," a novel electrostatic precipitator that operates in the temperature range between 500 and 750 F, at a gas velocity of 40 fps, and was the first large scale application of the design themes advanced in the preceding paper by Tigges and Karlsson.

The installation was put in at the Barking Station of the British Electric Authority on a bin and feeder fired pulverized coal unit with a rating of 150,000 lb per hr of steam. An economizer bypass was provided so the normal gas exit temperature from the economizer (400 F) could be regulated as desired to give a flue gas temperature range from 400 to 700 F.

One major problem was to be certain the electrostatic precipitator employed was kept so clean that re-entrainment of already collected particles in the collection zone and back emission in the ionization zone would be impossible. To accomplish this a selection of the electrostatic precipitator's collecting elements is cleaned periodically and at short intervals with a high velocity scavenging gas flow and then at longer time intervals by a soot blower. The blown-off dust, carried by the scavenging stream, goes to a mechanical after collector for removal.

The actual electrostatic collector operating at high temperature and with a gas velocity of 40 fps consists of twelve independent sectors, arranged in rotary symmetry. By means of rotating gas ducts, each sector passes through precipitating and cleaning periods in cyclic sequence. A mechanical collector precedes the electrostatic unit to lower the rate of growth of dust deposits on the electrodes.

The authors discussed the theory behind the precipitator design and described its application. Since the units have been in operation in their entirety only from July of this year no conclusive data were available

However in the first series of tests overall system efficiencies of 97 per cent were obtained indicating it is practical to extract fly ash from flue gas at 40 fps.

Industrial Boilers

The subject of industrial boilers was handled in a number of scattered sessions under the sponsorship of various divisions. The material presented ranged from general guides to rather specific descriptions of individual boilers and one paper introduced a direct-fired waste heat boiler for oil refinery service.

C. E. Rodenburg and **J. M. Brown,** Ford, Bacon & Davis, Inc., delivered their paper on "Industrial Boiler-Plant Design Factors" primarily as a guide for management and operating personnel. The purpose behind the presentation was to stress the authors' conviction that boiler plant design should be based on continuity of objective and policy. With such an approach one of the most severe limitations on the designer will be lifted. The authors claim that a design can be no better than the information on which it is based. A continued policy and objective will improve the design through greater information.

For example, an industrial plant planning to expand production or replace an outdated plant is looking for a high efficiency, low maintenance installation where investment costs run high. On the other extreme a decision to enter a new field or take a flier on a new product may indicate the lowest possible first cost of investment. The plant design to meet these vastly different requirements is certain to reflect the magnitude of these differences.

Similarly the anticipated load demand is vital to sound design. A combined electric-steam service depends upon the mutual relationship between the two demands to produce an economic design. A gross error in demand data could produce a plant throttled to partial capacity by a bottleneck in an undersized auxiliary.

The authors took the balance of their paper to single out certain other essentially non-technical considerations that influence plant design either directly or indirectly.

Thomas D. Coyne, Gibbs & Hill, in his paper "Typical Small and Medium Steam Plant Designs" presented a discussion of salient features of two industrial steam plants designed by his company. The objective was to extend the benefits of good engineering into small- and medium-sized steam-heating and process plants, particularly for coal-fired boiler units. The total cost based upon the initial installation of two boilers amounted to $7.19 per lb of steam for the 35,000 lb per hr boilers and $6.88 per lb for the 60,000 lb per hr units. For the ultimate three boiler plants costs were $6.20 and $6.31 per lb of steam, respectively.

Mr. Coyne presented two highly interesting tables in support of the above figures. They listed by major item classifications the installation, labor and total costs for the 35,000 lb per hr installation in the one case and for the 60,000 lb per hr unit in the second.

"The Dual Circulation Boiler in the Industrial Power Plant" by **R. A. Lorenzini,** Foster Wheeler Corp., reviewed the earlier discussions of this particular boiler design. Its prime purpose is to get around the problems facing industrial power plants with high makeups and high solids concentrations in the feedwater. This boiler design employs the principle of stage evaporation to maintain low concentrations without high blowdown rates. In dual-circulation units provisions are made to condense all or a portion of the steam in a secondary section. The design can be of either the single-drum or multi-drum type and the arrangement depends on several factors such as anticipated feedwater conditions, design pressure and permissible steam-release rates. The major advantage of the dual circulation principle is that the less expensive forms of chemical treatment consisting of hardness removal and silica reduction can be used.

Mr. Lorenzini discussed water treatment costs for four industrial areas using hot process and hot zeolite or employing demineralization. These costs comparisons included water treatment equipment charges as well.

"Operating Experience with Dual Circulation Boilers Using 100 Per Cent Makeup" by **J. R. Goff** and **J. E. Harden,** Standard Oil Co. of Indiana, was a follow-up paper to the Lorenzini one on the design of this particular boiler. The authors traced the background of their company's decision to go to a 1500 psi dual circulation boiler. One of the main reasons for the selection of this particular design was its expected ability to minimize the total solids and silica carryover as well as the required blowdown.

Results on this type boiler have been fine to date. Even though it is economical, because of a blowdown-heat recovery system Standard of Indiana installed, to operate with a 7.5 per cent blowdown and carry a boiler water concentration of 2000 ppm in the secondary steam-generating section, it would be possible, the authors stated, to carry a 3000 ppm concentration in this section and blowdown at a 5 per cent rate if there were not a heat recovery system. The 400- to 10-psi auxiliary turbines in the power station use the exhaust steam from the 1500 psi topping turbines. If the silica in the steam leaving the 1500 psi boilers is in any appreciable quantity it would show in these turbines first. They show no such indication.

Runs of 12 months were normal on the dual circulation boilers between maintenance shutdowns. Control has been relatively easy and rather extensive swings in high-pressure steam production have been handled smoothly. Gross efficiency has been maintained at from 86 to 87 per cent while burning oil or gas.

O. F. Campbell and **N. E. Pennels,** Sinclair Refining Co., collaborated on the paper "CO Boiler and Fluidized-Bed Steam Superheater on Sinclair Refining Co.'s New Fluid Unit at the Houston Refinery." The subject matter of this paper, a waste heat boiler, is a new approach to a long standing refinery problem. With it, formerly wasted, low heating value flue gas from refinery catalyst regenerators can be used. The boiler is coupled to a fluidized bed steam superheater to give the fluid catalytic cracking units an independent steam supply that is always under the control of the fluid unit's operator.

The heat input to the waste heat boiler comes from the sensible heat and carbon monoxide heat of combustion of the regenerator exit gases, and from supplementary fuel required to burn the carbon monoxide to carbon dioxide. Just as this CO boiler is a "first" so is the method of controlling the fluidized bed temperature by superheating steam a first. The difference between this superheater

and one in a boiler is the medium surrounding the coils. In a boiler the hot flue gas flows past the tubes whereas these coils are immersed in a fluidized bed. The superheater tubes are bombarded with very fine hot catalyst particles and the heat transfer rate is greater than in a conventional boiler. In fact as compared with a steam superheater of a fired boiler the heat transfer rate appears to be from five to seven times as much for the same temperature differential.

The operation of a respray to control the superheater temperature was described and many of the operating and design details were furnished. The heat absorbed by this respray superheater varies between 80,000,000 Btu per hr to 170,000,000 Btu per hr.

A number of advantages were cited by the authors for this new waste heat boiler in refinery service.

"A Study of Spreader-Stoker Reinjection Systems" was presented by **W. C. Holton,** Battelle Memorial Institute. Initially reinjection was a means of disposal for efficiency. The results of tests previously described in the literature are reviewed and compared. From these comparisons the author draws certain conclusions.

But before presenting these conclusions Mr. Holton describes his method of calculation and the establishment of a system of material balances on reinjection. The assumption has been made that the quantity of cinders originating from the coal fired and from the grate will be the same for tests at the same boiler rating when operating either with or without reinjection. An efficiency rating for reinjection from the standpoint of disposal is established in which this efficiency is defined as the ratio of the fly ash deposited on the grate to the total weight reinjected.

Fly-ash balances, fly-carbon balances and balances on heat loss to combustible in refuse were discussed and also their various influences on the final appraisal of a reinjection system.

In summarizing his paper Mr. Holton stated that the manufacturers of spreader stokers have achieved a measure of success in obtaining good efficiencies of reinjection without creating an unmanageable dust problem. Much work remains to be done, though, in perfecting existing systems and testing newer ones.

Marine Boilers in Stationary Practice

T. T. Judge, International Paper Co., recounted the experiences of his firm with a 4925 kva turbine generator and auxiliaries, two 32,000 lb per hr, 450 psig, 750 F boilers comprising a marine-type electric generating plan installed in 1948. All in all results were surprisingly good.

Many of the outstanding design features highly praised by the operators were adopted in the specifications for subsequent power equipment. The last six years' operating record backs up the operator's reactions since the units have performed at a remarkably high availability and with very low maintenance.

The author gave a report on the more important of the operating difficulties. In almost all instances the difficulties were readily overcome. Any major repairs could be held off or worked into the scheduled shutdown periods.

"Land Based Operation of Marine Boilers" presented by **E. T. Eyring** and **J. O. Rich,** Salt River Power District described how the combination of heavy load growth immediately after World War II and an extreme drought forced their company to put in for the second time steam-generating equipment. Since it was difficult to get quick deliveries in the post-war days they leased a U. S. Navy mobile steam plant in 1946.

Their initial operating days were made extremely difficult because of low quality fuel oil that slagged the fireside of the tubes and forced outages for cleaning every 8 to 10 weeks. When the boilers were converted to fire natural gas the slagging problem disappeared. From the spring of 1949 through the summer of 1952 the boilers were operated continuously except during annual maintenance periods. The authors feel the operation of these marine units was as satisfactory and reliable as any of the stationary steam-generating equipment operated by the Salt River Power District.

J. H. Colby, Diamond Alkali Co., presented his company's comments on marine boilers in a paper entitled, "Four Years Stationary Operation of Marine Boilers." Four oil-fired, divided-furnace marine boilers originally designed for U. S. Navy destroyers, class 692, were purchased as war surplus to meet a large post-war increase in paper and board production capacity of the Texas division of the Champion Paper and Fibre Co.

The author gave the details of the boilers and the alterations they underwent. One of these was conversion to natural gas firing. A second and perhaps most important alteration was in instrumentation to make the units as fully automatic as possible. Further a top flight water treatment program was set up to give the best possible water in the boiler despite heavy makeup requiring blowdown approaching 16 per cent or so.

Mr. Colby reported that these marine boilers have proved a dependable and economic source of steam. They have been utilized 70 per cent of the time but available 98 per cent. Steam cost for the past year has been 25 cents per million Btu and $28^1/_2$ cents per 1000 lb of steam. Natural gas has cost 13 cents per million Btu and represents most of the steam cost. Chargeable labor and supervision amounted to only 3 per cent of the cost; maintenance, about 1 per cent and power, depreciation, taxes and overhead, the remainder.

Residual Fuel Oil

Continuing interest in the problem of combating corrosion induced by certain constituents of residual fuel oils was indicated by the presentation of three papers, one dealing with work in Switzerland on chemical and physical factors in deposit formation, another concerned with modifications of fuel oil for gas-turbine use and a third having to do with evaluation of corrosion resistance of gas-turbine-blade materials.

P. T. Sulzer of Sulzer Bros., Winterthur, Switzerland, in a paper entitled "The Influence of Some Chemical and Physical Factors on the Formation of Deposits From Residual Fuels" attempted to explain the origin of free oil ash during combustion. The ash consists of solutions of metallic organic compounds and suspensions or emulsions of aqueous solutions of inorganic substances. In the combustion process all the inorganic compounds with relatively low vapor pressure are concentrated in the residual carbon particle. It is during the complete

combustion that the ash particles first begin to form, consisting of stable metallic oxides. It is important to distinguish between primary reaction of ash constitutents after combustion of all carbon, secondary reactions which occur in the gas stream between the flame zone and the place of deposition and tertiary reactions which take place at the deposition surface. Dr. Sulzer told of European investigations to prevent deposits through the use of additives and discussed tests carried out on a semi-closed cycle 20,000-kw gas-turbine plant. Very favorable results were obtained by adding a suspension consisting mostly of aluminum silicates. During a total running time of 2200 hr on treated fuels it was not found necessary to clean the turbine.

In a paper entitled "Modified Residual Fuel for Gas Turbines," **B. O. Buckland** and **D. G. Sanders** of General Electric Co. described a scheme for removing sodium from fuel oil. This is accomplished by mixing the oil intimately with water or a water solution of a suitable salt and then centrifuging the mixture. Ninety per cent or more of the sodium is washed out and the calcium content is substantially reduced. Turbine tests of 50- to 1500-hr duration using these desalted fuels show that deposits can be almost eliminated by keeping both the sodium and the calcium below 10 ppm. Treating vanadium-containing fuels with calcium or magnesium shows that, below 1650 F, magnesium is a better inhibitor than calcium. The presence of lead in sufficient quantities in the fuel spoils the inhibition of vanadium by means of magnesium. With further development it is possible that the present costs of 14¢ per bbl for treatment can be reduced to three to five cents. Even should residual fuel oil become less generally available, the lessons learned in burning it can more or less directly be applied to the burning of coke, pitch or whatever other petroleum product appears in its place.

Three engineers from Westinghouse Electric Corp., **W. E. Young, A. E. Hershey** and **C. E. Hussey, Jr.,** presented a paper entitled "The Evaluation of Corrosion Resistance for Gas-Turbine-Blade Materials." Surface analysis of gas-turbine-blade material before and after exposure to the combustion products of residual fuel oils demonstrates the corrosive effect of these products, and a measurable indication may be obtained in a fraction of the testing time required to produce appreciable weight loss. Surface analysis has the further advantage that it is possible to measure corrosion in specific regions on a specimen where the specimen has been exposed to a gas-flow pattern with a well defined temperature profile. Weight loss measurements following lengthy tests have shown good agreement with this method of analysis. The fusion temperature of the fuel ash appears to be a reliable criterion for judging the corrosivity of residual fuel oil, and good correlation has been obtained between ash-fusion temperatures and corrosion both for untreated oils and oils with additives.

Steam Turbine Locomotive

In a joint effort by the engineers and designers of a steam locomotive placed in service on the Norfolk & Western Railway last summer, **P. D. Evans** of the Steam Division of Westinghouse Electric Corp., **C. C. Hamilton** of the Babcock & Wilcox Co. and **R. P. Stoddart** of Baldwin-Lima-Hamilton Corp. presented a descriptive paper entitled "Coal-Fired Steam Turbine-Electric Locomotive for Norfolk and Western Railway." Several features which have proved satisfactory in marine and stationary practice are included for the first time in the particular combination chosen for this locomotive design. The 600-psig, 900-F watertube boiler, with complete automatic control of fuel and air to the furnace as well as feedwater to the boiler in exact proportion to steam demand, and the self-cleaning traveling grate on which the coal is burned are entirely new to locomotive practice.

The locomotive has a 6-6-6-6 wheel arrangement, each of the twelve axles being powered by a direct-current series motor of the type generally used for electric traction. Its continuous tractive effort is estimated at 144,000 lb. at 9 mph.

The boiler is of the low-head, longitudinal-drum natural-circulation water-tube type incorporating a superheater, economizer and air heater. Coal is delivered by a modified railroad-type steam-jet spreader stoker, and a forward moving Rotograte continuously discharges ash at the firing end. The ash is distributed in the long flat ash pan by intermittent blowing of steam jets.

The steam turbine is of the noncondensing impulse type with a rating of 4500-hp input to the generator for traction plus approximately 200 hp for auxiliary power. At rated output the turbine operates at 8000 rpm, while its idling speed is 4800 rpm. The two direct-current traction generators which are mounted back to back are driven through a single helical-type reduction gear at a speed of 900 rpm at rated load.

"Performance of Norfolk and Western's Experimental Coal-Burning Steam-Turbine Electric Locomotive" was the title of a paper by **I. N. Moseley,** research and test engineer of the Norfolk and Western Railway. He described full-scale dynamometer tests which were begun on July 19 and completed on October 2, 1954. Westbound tests on the Radford Division showed the turbine locomotive capable of handling 3600 tons of empty coal hoppers from Roanoke to Bluefield. Eastbound tests on the same division established a rating of 11,500 tons. By comparison to a 2-8-8-2 mallet locomotive, the turbine-driven engine made 4 to 13 per cent less speed on mountainous divisions but showed a fuel saving of 20 to 30 per cent, while handling the same tonnage. It was also capable of pulling between 18 and 27 per cent more tonnage with fuel savings ranging from 19 to 37 per cent. Similar results were shown on relatively level divisions, where again speed was lower than conventional steam locomotives now serving these regions, while fuel cost per thousand gross ton-miles was reduced by a factor of 29.9 per cent on eastbound runs.

Canned Motor Pumps

A series of three papers on the development of canned motor pumps was presented by engineers of the Westinghouse Electric Corp. In the first of these by **B. Cametti,** "Pumping in Hermetically Sealed Systems," related experiences on one size of pump operating in

water systems at about 450 F and at around 2000 psig are presented. The hydraulic capacity at full power necessitated the pumping of 4000 gpm while developing a total dynamic head of 100 psi. The conventional type shaft seals have been eliminated by enclosing the entire motor and pump assembly into one hermetically sealed housing. To date, several sizes of units have been developed having capacities ranging from 30 gpm and 30 psi to 4000 gpm and 100 psi. Operating time on existing units varies from as much as 20,000 hr on the smaller sizes to 10,000 hr on the larger ones.

The second paper, "Design and Operation of Small Canned Motor Pumps," was presented by **A. J. Mei,** who enumerated the chronology of the designs beginning with the original oil-cooled stator windings and progressing to the present silicone-insulated stators with water-cooled frames. During the development of these pumps every effort was made to use standard commercial practice and materials where acceptable. Some modifications and new techniques were required, including the use of such materials as carbides, precipitation-hardening stainless steels, age-hardened Inconel "X" and "W" and tests of the compatibility of materials in contact while immersed in moderate and high-temperature water.

W. M. Wepfer and **E. J. Cattabiani** presented the third paper, "Water-Lubricated Bearing Development," in which they outlined the extensive test programs under taken to determine the most satisfactory materials. The best performance is observed when both journal and bearing are in the very hard range, and this is equally true if one of the bearing elements is carbon-graphite, a definite preference showing for the harder grades. The ceramic group has an impressive record of success as have many grades of tungsten-carbide and some of the stellites. The soft and medium-hard materials, especially nickel-bearing alloys, are generally inferior as bearing components. Nitrided stainless steel performs well with hard grades of carbon-graphite, though some corrosion resistance is lost by nitriding.

Gas Turbines

Two companion papers on gas-turbine operating experience were presented by engineers of the General Electric Co. The first of these, "Operating Experience on General Electric Gas Turbines" by **W. B. Moyer** summarized the experience on 71 units which have accumulated over 345,000 hr of operation.

Eight simple-cycle single-shaft machines are generating power and have operated during 11 installed years for a total of 42,611 hr and over 191,000,000 kwhr for an average load of 4500 kw. The major maintenance items on these turbines are combustion liners, first-stage-nozzle repairs, controls and accessories maintenance, with the remainder of the turbine showing little appreciable wear. A single regenerative-cycle two-shaft machine has accumulated two installed years of operation of 2690 hrs in peak load and standby power generation, but the experience is insufficient to predict adequately what differences in maintenance this type gas turbine entails. Ten regenerative-intercooled-cycle two-shaft turbines have been manufactured and have operated for 15 installed years totaling 32,197 hr at an average electrical load of 3750 kw. While the first six of these units experienced outages to modify thrust bearings, flexible couplings, second-stage buckets, vibration and gears, these conditions have all been corrected and the turbines are now operating satisfactorily. On the Union Pacific Railroad 27 of the simple-cycle single-shaft machines have accumulated a total of 16 locomotive years, 72,383 hr and over 1,700,000 miles of operation. Running maintenance has been higher than overhaul maintenance and has included inspection and replacement of combustion liners, change of fuel nozzles and elimination of a valving seizure condition in fuel pumps. In the field of natural-gas pumping, 38 regenerative two-shaft machines have operated 37.5 installed years for a total of 190,734 hr. The machines in this application have shown advantage over reciprocating engines by reducing operating labor 5 to 1, lubricating-oil consumption 10 to 1 and water consumption 4 to 1.

In his conclusion Mr. Moyer stated that the major improvements required to make residual fuel turbine operation equal to that of natural gas lie in providing noncorrosive fuel and in further improvement of the combustion system. The overall availability of gas-turbine plants shows a steadily improving picture even though it is already very creditable, averaging close to 90 per cent. This improvement will be accomplished through reduction of outage time due to mechanical failures and reduction of time-consuming combustion-chamber and other inspections heretofore required. Reliability of these plants is shown by their low unscheduled outage time which ranges from one per cent in central-station applications to 6.8 per cent in the first year of operation on gas-pipeline-pumping installations.

In the companion paper, "Gas-Turbine Bucket Operating Experience and Bucket-and-Wheel Design Method," **T. N. Hull, Jr.,** stated that in a total operating time of 360,000 hr unscheduled outages caused by turbine buckets has been 50 hr or 0.014 per cent of the total period, including substitution of the spare locomotive gas turbine. This experience with General Electric commercial gas-turbine buckets compares favorably with the reliability of modern steam turbines. To date no bucket maintenance has been encountered in any of the machines operating on nautral gas, while a limited amount of maintenance has been associated with residual-fuel-fired machines. Design temperature of the first-stage gas-turbine buckets at the bucket pitch diameter ranges from 1150 to 1300 F, with a turbine-inlet average temperature from 1400 to 1525 F. The discharge from the combustion changers does not have an even temperature distribution which may cause portions of the bucket to operate at a much higher temperature than the thermodynamic design temperature. In another part of the paper the author presented a method for making the preliminary mechanical design of a gas-turbine bucket dovetail and wheel.

A very comprehensive paper discussing a number of ways of utilizing the energy in gas-turbine exhaust was presented by **A. A. Hafer** and **W. B. Wilson** of the General Electric Co. under the title "Gas-Turbine Exhaust-Heat Recovery." Following a tabulation of minimum permissible stack temperatures for various fuels and an analysis of losses associated with steam plants, diesel engines and gas turbines, the authors discussed combined steam-gas turbine plants. They pointed out that of the

97 gas turbines installed by their company 57 per cent had some provision for utilizing exhaust heat, including regenerators, feedwater heaters and waste-heat boilers. Mention was also made of the use of exhaust gas to dry various manufactured products.

Safety in Nuclear Engineering Operations

R. L. Doan of the Phillips Petroleum Co. presented a paper entitled "Basic Safety Procedures in Reactor Operation" which was concerned primarily with the Materials Testing Reactor (MTR) of the AEC Reactor Testing Station at Idaho Falls, Idaho. The operational safety of a nuclear reactor hinges on core geometry, excess reactivity, reliability of control system and coolant and adequacy of instrumentation. Mr. Doan pointed out that it is the practice to prepare a "Hazards Survey Report" for reactors constructed in this country. These reports are reviewed and discussed in detail with the operating contractor's personnel by a reactor safeguards committee which acts in an advisory capacity to the Atomic Energy Commission.

The basic philosophy of the reactor control for the MTR is to provide several independent devices for shutting the reactor down and none for starting it. Only the operator can bring the reactor to power, and his actions are at all times rendered ineffective if they do not conform to a predetermined safe procedure. Even if they do conform, any potential hazard that develops will override the operator's action.

Reactor-control instrumentation is based on signals arising in the neutron-detection instruments located at suitable positions inside the reactor structure. From these signals the logarithm of the neutron level and reactor period are developed. The central problem of the control system at MTR is to provide continuous measure ment of neutron-flux level over a range from 10^{-11} of full power, when there is already significant neutron multiplication, up to full power.

A report on safety lessons learned from the accident which occurred in December 1952 at the Canadian Chalk River NRX experimental reactor was presented by **G. W. Hatfield** of Atomic Energy of Canada Ltd. in a paper entitled "A Reactor Emergency—with Improvements Adopted as a Result." The accident was caused by a mechanical failure in the shutoff rod system, resulting in a power surge which led to overheating of some of the reactor components.

From the experiences gained in the decontamination and reconstruction of this reactor, a number of improvements were adopted which should be considered in the design of future reactors:

1. In building any nuclear reactor the ease of dismantling the unit must always be incorporated in the original design.

2. When building a reactor which requires heavy or light water as a coolant, all surfaces below the reactor should be of a smooth finish and nonabsorbent. Because of its absorption properties and difficulty in cleaning, bare concrete is a poor surface to be exposed to radio activity accompanied by a liquid.

2. When building a reactor which requires heavy or light water as a coolant, all surfaces below the reactor should be of a smooth finish and nonabsorbent. Because of its absorption properties and difficulty in cleaning, bare concrete is a poor surface to be exposed to radioactivity accompanied by a liquid.

3. All panel boards for instruments and equipment that must be located below the reactor should be suspended from the ceiling instead of attached to the floor. This is to prevent contamination at bolt holes and other points of points of attachment.

4. For liquid reactors it is desirable that a large funnel be installed directly beneath to collect any active solution that may leak. This material should be piped to one controlled central point.

5. All horizontal surfaces in the main reactor building, including overhead girders, cranes, etc., should be sealed with a material of smooth finish, thereby easing decontamination. For the same reason a smooth surface should also be applied to walls and other vertical surfaces.

6. The ventilating system in a reactor building should be designed with enough extra inlets to provide a quick means for attaching portable connections in special locations when emergencies arise.

"Disposal of Radioactive Wastes" was the subject of a paper by **Abel Wolman** and **A. E. Gorman** of the Atomic Energy Commission. Although there are adequate means to control waste at present, they are quite expensive, and more economical ways will have to be found if atomic energy is to compete favorably with other fuels. The Atomic Energy Commission has placed research and development contracts with universities, private industry, the National laboratories and other federal agencies to evaluate various waste-disposal methods and particularly the extent to which the ground, surface waterways and the air may be used to store, shield, dilute and disperse radioactive wastes.

Feedwater Heaters

In presenting the user's viewpoint on feedwater heaters, **S. M. Arnow** of the Philadelphia Electric Co. defined an economical power plant as one which *works* continuously, unobtrusively and trouble-free. From this viewpoint he added that it is far less important that the heater have the exact number of tubes than that it have the exact number of vents at the proper places to prevent the tubes from corroding; less important to place the heaters at the exact theoretical point in the cycle than to be sure that the joints do not leak with any fluctuation in load; less important that certain terminal differences be maintained than that baffles and stay rods remain intact.

To carry out the mutual responsibility shared by manufacturers and users Mr. Arnow urged heater designers to concern themselves with as much enthusiasm for mechanical design as they have heretofore expended upon thermal and heat-transfer considerations. This means job follow-up after installation, study of failures, and determination of causes to prevent repetition. Users on the other hand, must write specifications that will allow designers to make free use of their experience and not restrict them unduly by specifying details within very narrow limits. Mr. Arnow added that it is enough to specify what heaters *should do* and let the designers worry about *how* it should be done.

*Fresh Water from Sea Water Evaporators at the Morro Bay Steam Plant**

By ALBERT W. BRUCE

Mechanical Engineer, Pacific Gas and Electric Company, San Francisco, California

This article outlines the alternative fresh water sources that were considered and explains why it was finally decided to install sea water evaporators. A description of the evaporator cycle and equipment required is presented along with the cost of making fresh water from the sea.

AMONG the many requirements for a satisfactory steam plant site is a reliable source of fresh water for boiler feedwater makeup and general use in the station. It sometimes happens that other site considerations such as availability of land and condenser cooling water, satisfactory foundation conditions, ease of electrical interconnection to the system, accessibility of highways or railroads and suitable delivery for fuel are satisfactory; but an adequate supply of fresh water presents a problem. This situation existed at Morro Bay which was a desirable site except for fresh water.

The cost of properly conditioned makeup water for the boilers is appreciable, and to obtain it from the sea does not represent as much of an increase over more conventional sources as one might think unless some study has been given to the problem. Actually the cost of raw water is only one of the factors that make up the total cost of fresh water before it is finally fed into the boiler. Even though the sea water evaporators do increase the cost somewhat for this one item, it can be shown that the effect on the overall plant cost can be such as to make the site still attractive.

* Presented by the Power Division at the Professional Divisions Fall Conference, American Society of Mechanical Engineers, San Francisco Section, San Francisco, California, November 12, 1954.

The initial installation at Morro Bay Steam Plant will consist of two 156,250-kw reheat turbine-generators and two 1,135,000-lb per hr boilers designed for turbine inlet conditions of 1800 psig, 1000 F with reheat to 1000 F. The first unit will go into operation early in 1955 and the second in 1956.

The amount of fresh water required for these first two units including some margin was determined to be 100 gpm. Of this amount about 2–3 gpm will be required for drinking and sanitary use. Of the remainder, approximately half will be used for boiler make-up and the rest for general utility purposes. For emergency fire fighting, fresh water will be taken from the 500,000-gal standpipe located on the bluff above the plant with sea water being used as a backup.

The various methods of producing fresh water which were studied will now be discussed briefly.

Municipal Water Supply

The first source of water investigated was the local municipal water supply of Morro Bay and vicinity. Except for the small amounts of drinking and sanitary water required at the steam plant, the local supply was not available because of the limited amount.

Wells on the Steam Plant Property

The next source of water investigated was wells on the steam plant property. There were two wells on the property when it was purchased. Because of the proximity of the wells to the ocean, there is the possibility that they may become contaminated with salt water if they are pumped too heavily. In this region, where the rainfall is light and in cycles, the wells were not considered adequate to give an assured water supply. However they will be

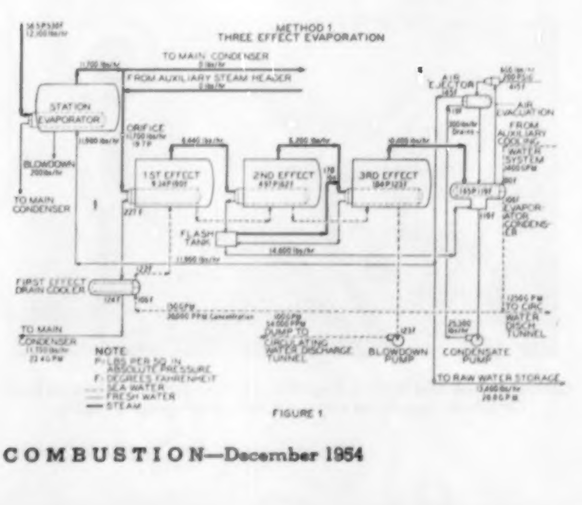


FIGURE 1

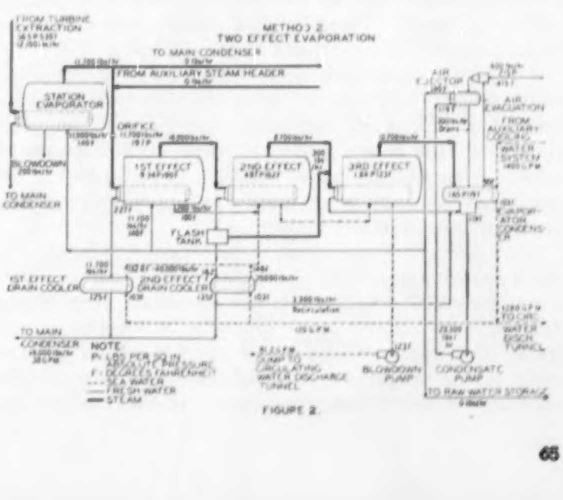


FIGURE 2

used for general utility purposes to the extent of their capability.

Effluent Water From the Sewage Treatment Plant

The Morro Bay Sanitary District is constructing a sewage treatment plant north of the steam plant which will treat the sewage from Morro Bay and the communities as far north as Cayucos. The sewage treatment plant will not be of the final type, so although the water effluent is sanitary, it will contain detergents which would have to be eliminated by additional treatment to make the water suitable for station evaporator makeup. Because of the cost of the additional treatment and the variation of flow of the municipal plant, it was decided the use of the effluent water was not feasible.

Construction of a Reservoir

Morro Bay Steam Plant is located at the mouth of Morro Creek, but this creek did not have a good dam site and it was decided to study the water flow in Toro Creek which is in the next major watershed to the north. The cost of construction of the dam across Toro Creek including the necessary relocation of roads and petroleum pipe lines to avoid the reservoir, made this alternative source of water more expensive than sea water evaporators for two units, although for four units constructed initially, the annual costs would be approximately the same.

Sea Water Evaporators

The next method studied was the use of sea water evaporators to produce fresh water. The capital expenditure for two units was less than the cost of the reservoir so the annual cost for two units was lower than that for the reservoir even though the operating costs for the evaporators were higher than those for the reservoir. Because of this lower cost it was decided to install sea water evaporators to produce fresh water for the first two units.

The original specifications for the evaporator system were determined by engineers of the Pacific Gas and Electric Company. The final system was designed by the engineers of Pacific Gas and Electric Company and the Bechtel Corporation who are the constructors of the plant.

For each of the first two units there will be installed a triple-effect evaporator designed to produce 50 gpm (72,000 gal per day). Of this amount approximately half is for boiler makeup and the remainder is for general utility purposes. Drinking and sanitary water will be obtained from the local water system of Morro Bay.

As about half of the water to be produced from the sea water evaporators need not be of the purity required for boiler makeup, it was decided to specify that the solids content of the water produced could be as high as 50 ppm. A part of this water will then be redistilled in the station evaporators to produce water of a purity of less than 1.0 ppm for boiler makeup.

The sea water evaporators were designed to be of sufficient capacity to supply all the fresh water requirements even though the wells were not available, thus giving the plant an assured water supply. It is expected normally that there will be water available from the two wells on the property to be used for utility, standby fire and miscellaneous water purposes. In this case the sea water evaporators will only have to supply the makeup requirements for the station evaporators. The water from the wells is too hard for direct feed to the station evaporators and would require water treatment. It was decided not to install a water treatment plant at this time as the effluent from the sea water evaporators is satisfactory for direct feed to the station evaporators.

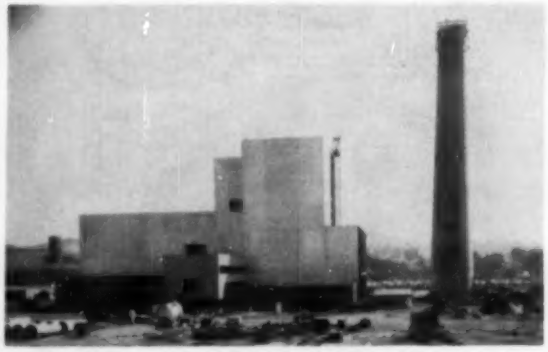
Description of Evaporator Cycle

Three principal methods of operation of the sea water evaporator will be used:

1. Condensate effluent from the sea water evaporators is used for station evaporator makeup as required and the remainder pumped to the 500,000-gallon standpipe to be used for general utility purposes. During periods of large boiler makeup requirements, part of the steam vapor from the station evaporators will be routed to the main condenser and only sufficient steam will be supplied to the first-effect sea water evaporator to generate the water required for station evaporator makeup.
2. All condensate effluent from the sea water evaporators is used as makeup to the station evaporator.
3. All condensate effluent from the sea water evaporators is used as a supply to the standpipe. This case would probably be infrequent and would mean that boiler makeup was not required. Live steam would be used as there would be no vapor supply from the station evaporators.

Method 1. Three-Effect Evaporation

As illustrated in Fig. 1, the steam for the heating tubes of the first effect of the sea water evaporator is the vapor from the station evaporator normally, but also can be supplied through reducing valves from the auxiliary steam header for Method 3. The condensate from the first-effect evaporator tubes drains down through the first-effect drain cooler to the main station condenser where it becomes a part of the boiler feedwater. The vapor (steam) from the first-effect evaporator is the supply for the second-effect evaporator, and in turn its vapor is the supply for the third-effect evaporator. The vapor from the third-effect evaporator is condensed in an evaporator condenser. The pressure in each vessel is a partial vacuum which reduces the temperature and there-



Office end of the Morro Bay Steam Plant as it looked in late October, machine shop on left, warehouse, right.

fore reduces the deposits of minerals on the tubes. The absolute pressures at rated capacity are, for the first-effect evaporator shell, 9.34 psia; second-effect, 4.97 psia; third-effect, 1.84 psia; and for the evaporator condenser, 1.65 psia. This high vacuum in the evaporator condenser is maintained by a two-stage twin-jet air ejector.

The makeup water for the evaporators comes from the auxiliary salt water cooling system after the water has gone through the cooling water heat exchangers. 1400 gpm of sea water flows through the evaporator condenser, 150 gpm of which is fed to the first-effect evaporator through the first-effect drain cooler. The sea water passes through the succeeding effects and 100 gpm leave the third-effect evaporator as blowdown at the rated evaporator output of 50 gpm. The concentration of solids is increased 50 per cent from 36,000 to 54,000 ppm. Because of the high vacuum in the evaporator a blowdown pump is used to pump the brine to the condenser discharge tunnel. The remainder of the cooling water from the evaporator condenser is also discharged to the discharge tunnel.

It is interesting to compare the above 54,000-ppm salinity with that of the Great Salt Lake in Utah which is about 150,000 ppm.

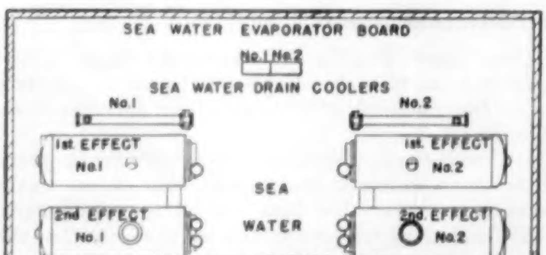
Starch and boiler compound will be introduced into the sea water makeup to the sea water evaporator to modify the mineral deposits on the tubes so they are more easily removed.

Method 2. Two-Effect Evaporation

As illustrated in Fig. 2, the first-effect sea water evaporator is used as a station (high purity) evaporator and only the second and third sea water evaporators are used for generating steam from the sea water. The purpose planned for this is to give a balance between the new water generated and the steam required to generate it. In Method 1, 2.2 times as much fresh water is made as steam supplied.

As in Method 1, the vapor from the station evaporator

ARRANGMENT OF EVAPORATOR EQUIPMENT



will generate steam from the first-effect sea water evaporator. However the makeup water supplied to the shell will be the 50 ppm effluent from the second and third effect sea water evaporators. With this feedwater it is expected to obtain steam with a purity of 2 ppm. Combining this effluent with the 0.5 ppm effluent expected from the station evaporator will give a combined water purity of about 1 ppm.

The vapor from the first-effect evaporator will supply the second-effect evaporator and will drain through a second drain cooler to the main condenser. In order to keep the makeup water requirements in balance with the steam generated, part of the drains from the second-effect evaporator heating tubes are combined with the effluent from the sea water evaporator condenser after first passing through the second-effect drain cooler.

Method 3. Three-Effect Evaporation With Live Steam

The process in the sea water evaporators in Method 3 is the same as Method 1. The difference is that live steam, supplied from the auxiliary steam header connected through reducing valves from the boiler, is the source of heating steam to the first effect of the sea water evaporators.

Arrangement and Description of Evaporator Equipment

The sea water evaporators will be located in the turbine room on the intermediate floor level 13 ft above the ground floor level. The "high purity" station evaporator is located on the turbine floor level 26 ft above the ground floor. The evaporator condensate pumps and blowdown pumps are located on the ground floor directly below the evaporator condenser. The auxiliary salt water pumps which supply the cooling water for the evaporator condensers and the feedwater for the evaporators are located in the screen house on Morro Bay. 1400 gpm of sea water are pumped in a 10-in. line through the cooling water heat exchanger to the sea water evaporators.

The sea water evaporator system for each of the first two units will be the same. The description of the major parts of the equipment for each set follows. The evaporators and other heat exchanger equipment are manufactured by Lummus Co.

1. THREE EVAPORATORS
   $^5/_8$-in. thick welded copper bearing steel shell 72-in. O.D. × 20 ft 0 in. overall length, with welded steel shell cover and welded steel bonnet and steel splash-type vapor separator. 1050 sq ft of 1-in. O.D. 16 BWG aluminum brass straight tubes will be used with naval rolled brass tube sheets and cast bronze floating head covers. On the first effect only of Unit No. 2, for experimental purposes, there will be installed tubes of 70-30 cupro-nickel inhibited with 0.5 per cent Fe and tube sheets of 90-10 cupro-nickel inhibited with 1.5 per cent Fe. All tubes will be installed with a $1^3/_4$ in. square pitch to aid in cleaning the tubes.

2. ONE EVAPORATOR CONDENSER
   Two-pass divided flow with welded copper bearing steel shell 40-in. O.D. × 15 ft 10 in. overall length with cast iron water boxes and water box covers and steel support plates and air baffles. 1150 sq ft of $^3/_4$-in. 18 BWG aluminum brass tubes will be used with naval rolled brass tube sheets. For Unit No. 2, the evaporator condenser will have, for experimental purposes, tubes of 70-30 cupro-nickel inhibited with 0.5 per cent and naval brass support plates and air baffles.

3. ONE FIRST-EFFECT DRAIN COOLER
   0.365-in. wall $10^3/_4$-in. O.D. seamless steel pipe shell with

cast iron channel, channel cover and return covers, 14 ft 1 in. overall length, 153 sq ft of $^3/_4$-in. × 18 BWG × 12 ft 0 in. long aluminum brass tubes. Unit No. 2, only, will have naval bronze channels, channel covers, and partition plates.

4. ONE SECOND-EFFECT DRAIN COOLER

Similar to first-effect drain cooler, except that it is only 5 ft 1 in. overall length with 36 sq ft of $^3/_4$-in. × 18 BWG × 3 ft 0 in. long tubes.

5. ONE AIR EJECTOR

Twin type, double effect. Operating pressure 3.35 in. Hg abs, using 600 lb per hr of 200-psig steam from auxiliary steam system. Air and water vapor removal equivalent to 220 lb per hr.

6. TWO EVAPORATOR BLOWDOWN PUMPS—ALLIS CHALMERS MFG. CO

150 gpm—18 ft head, 19 per cent chromium, 10 per cent nickel, 2.5 per cent molybdenum alloy steel casing with Type 316 stainless steel trim horizontal centrifugal pump.

7. TWO EVAPORATOR CONDENSATE PUMPS—FAIRBANKS, MORSE & CO.

65 gpm, 170 ft head, cast iron casing, bronze trim, horizontal centrifugal pumps.

8. PIPING

a. Piping for salt water use will be cast iron for sizes $2^1/_2$ in. and above, and for the smaller size piping Type 316 stainless pipe will be used. For larger sizes, cast iron body valves with Type 316 stainless steel trim will be used and for the smaller sizes Type 316 stainless steel valves will be used.

b. Piping for steam and evaporator vapor will be carbon steel and the valves used will be welded end, cast steel body with stainless steel trim.

c. As most of the evaporator system will be under a vacuum, the number of valves is being kept to a minimum to reduce the possibility of air leakage into the evaporators.

Costs of Sea Water Evaporator System

Because of the considerable interest shown recently in methods of obtaining fresh water from the sea to supplement the supplies available in the State of California, a word about the cost of producing the water at Morro Bay Steam Plant should be interesting.

Assuming a fuel oil cost of $1.75 per bbl, a 100 per cent rated load on the evaporators, and steam extraction from the turbine, the cost per 1000 gal is estimated to be $1.96. This includes the annual fixed charges on the capital costs of the sea water evaporator equipment, costs for equivalent power loss from turbine extraction, chemical treatment and auxiliary pumping. No charge has been included for labor as no additional labor will be required above the normal complement of operators in the steam plant. If auxiliary live steam from the boilers is used, the cost per 1000 gal is estimated to be $2.58.

It is interesting to compare these costs with the water costs in various situations listed below:

	Cost per 1000 gallons
Irrigation Water at $10 per acre foot	$0.031
Water from average irrigation pumping plant in California	0.017
San Francisco Municipal Water (4,320,000 gallons per month, average 100 gpm)	0.247

Except for the sea water evaporator method, it will be necessary to add to the above costs the expense of treating the raw water to make it a suitable supply for the station evaporator. In addition to the water treating plant, it also will be necessary to install an evaporator condenser for condensing the steam from the station evaporator. Assuming that the well water was used at Morro Bay, the cost for treating an average flow of 56 gpm is estimated to be $0.93 per 1000 gal. This cost includes the fixed charges plus the operating and maintenance costs for the water treating equipment.

Both sets of evaporators are expected to go into service in February, 1955. At that time they first will be used for producing boiler makeup during the starting-up procedure for the first boiler.

The use of sea water evaporators at the Morro Bay Steam Plant demonstrates that it is possible to locate a plant on the seashore if the site is desirable but does not have fresh water. A method has not been found for producing fresh water from the sea which is economical for agricultural use, but at this steam plant sea water evaporators were the least costly of the choices that were available for our particular situation.

IEC Prime Movers Committees Meet

The work of the International Electrochemical Commission of which the ASME is a member, interrupted during the second world war, has gradually been reactivated since July, 1946. The programs of the prime movers committees were resumed and sufficiently advanced to have these technical committees meet during the Golden Jubilee of the IEC in Philadelphia, Pa., at the University of Pennsylvania during September 1–16, 1954.

IEC/TC/5 on Steam Turbines held four days of meetings—September 7, 8, 10, 11—with representatives present of: Canada, Belgium, France, Germany, India, Italy, Sweden, Switzerland, United Kingdom, and the U.S.A.

The three secretariat documents relating to steam turbines presented for consideration covered:

(1) Part 1, the Purchase Specification (proposed revision of IEC Publication 45)

(2) Part 2, Rules for Acceptance Tests (proposed revision of IEC Publication 46)

(3) Appendix to Rules for Acceptance Tests (revision of IEC Publication 46A.

It was agreed that for the present the Rules for Acceptance Tests will only provide for the conduct of tests and for the computation of the results for turbines of the following types:

(a) Complete expansion condensing turbines in which all the steam enters at one pressure and all the steam leaves at a pressure less than that of the atmosphere.

(b) Condensing turbines similar to (a) except that the steam is reheated after partial expansion.

(c) Condensing turbines similar to (a) but operating on a regenerative cycle, i.e., steam being extracted from one or more stages solely for heating the unit's own feedwater. This class may include turbines that supply extraction steam for heating make-up feedwater, also evaporators and deaerators serving as extraction heaters.

(d) Condensing turbines similar to (a) but provided with both the special features described in (b) and (c).

(e) Non-condensing and back-pressure turbines in which all steam enters at one pressure and all steam leaves at a pressure equal to or greater than that of the atmosphere.

Atomic Energy in Industry Topic of Three-Day Conference

THE three-day special meeting of the National Industrial Conference Board Oct. 13, 14 and 15 in New York City, on the general subject of Atomic Energy in Industry, ranged extremely wide in coverage. The official program listed some twelve areas of discussion many of which are only of borderline interest to the power and steam generation fields.

Company Planning

Martin Frisch, vice president, Foster Wheeler Corp., gave an excellent summary of the reasons behind his company's election to participate in the development of nuclear energy for possible power generation. Mr. Frisch employed the technique of questions and answers and selected several key questions to picture his company's interest.

Question No. 1: What might be considered plausible quantitative forecasts indicative of immediate and long-term demands for conventional and nuclear fuel-consuming electric power generating units?

Answer: Fig. 1, reproduced p. 70, shows curves of actual average hourly electric power production rates, peak load requirements, total and steam electric plant capabilities of the electric industry from 1920 through 1953 in thousands of megawatts. These curves were extended by extrapolating the trend figures from 1945 to 1953 to show trends from 1953 through 1980. The slopes of these extended trend lines suggest the electric industry might double its capability about every eight years. This would give a 1980 peak of 800,000 mw and an installed capability of over 900,000 mw as contrasted to the 1953 year-end capability of 95.5 mw.

In addition Fig. 1, lines n and N, show the Foster Wheeler Co. guesses on the yearly increases in hourly capabilities of nuclear steam electric stations and the corresponding total capability of nuclear fuel-fired units operative each year through 1980. These guesses were predicated on the first nuclear unit of 60 mw going into service in 1956 or early 1957 and a gradually increasing rate of new units from then on until by 1980, 27,000 mw, or one-half the forecast steam plant capabilities of 54,000 mw, will be nuclear fuel-burning units.

Question No. 2: To what extent might recent and potential nuclear power developments jeopardize the future of the conventional fuel-fired steam generator business?

Answer: Table I, below, gives estimates of the total value, in millions of 1953 dollars, of the potential future U. S. business in conventional and nuclear-fired steam electric power stations and steam generating units. The figures this table gives allays any fears of any appreciable shrink in the conventional boiler field within the next ten years. By assuming that the cost in 1953 dollars per kilowatt of conventional steam plant capability, uncorrected for possible technological developments or changes in the value of the dollar, remains at $145 and that the average station cost of nuclear power plants will gradually decrease from $300 per kw of capability in 1960 to $189 in 1980, nuclear power installations will increase so that long range overall prospects seem encouraging.

Question No. 3: What are the dimensions of the engineering, manufacturing and construction tasks to be anticipated by potential suppliers and constructors of nuclear and conventional fuel-fired steam generating units?

Answer: Table I indicates the values included in the owner's costs of the anticipated services to be furnished by architect-engineers, equipment designers, and manufacturers and constructors of complete steam production plants, and the steam generating units, respectively, for fossil and nuclear-fired steam electric plants for a number of sample years.

Current Outlook for Costs

W. Kenneth Davis, U. S. Atomic Energy Commission, cautioned that "in considering the time scale for the development of economic nuclear power one must be careful not to substitute hopes for facts with regard

YEAR	1953			1960			1965			1970			1975			1980		
TYPE OF FUEL (F = FOSSIL, N = NUCLEAR, T = TOTAL)	F	N	T	F	N	T	F	N	T	F	N	T	F	N	T	F	N	T
CAPABILITY INCREASE FORECASTS - THOUSANDS OF MEGAWATTS																		
NET ALL PLANTS			7			14			22			33			52			81
NET STEAM PLANTS	54	0	54	98	02	100	144	06	150	210	20	230	280	70	350	270	270	540
REPLACEMENTS *	2	0	2	05	0	05	07	0	07	09	02	11	15	02	17	23	02	25
TOTAL ADDITIONS	56	0	56	103	02	105	151	06	157	219	22	241	295	72	367	293	272	565
COST TO OWNER - MILLIONS OF 1953 DOLLARS																		
FOR ENTIRE STEAM ELECTRIC PLANT ADDITIONS	810	0	810	1500	60	1560	2190	156	2346	3180	500	3680	4280	1580	5860	4250	5400	9650
FOR STEAM PRODUCTION PLANT ADDITIONS ONLY	398	0	398	735	44	779	1081	113	1794	1570	342	1912	2105	1021	3126	2043	3244	5287
COMPLETE STEAM PRODUCTION PLANT — ENG DESIGN DEV — ENG. ARCHITECT — B (B = BEFORE PURCHASE)	08			25	02		22	06		31	17		42	51		41	16	
ENG. ARCHITECT — A (A = AFTER PURCHASE)	240			48	18		70	54		101	15		137	45		133	133	
ENG. ARCHITECT — T (T = TOTAL)	25	0	25	50	20	52	72	60	78	104	17	121	141	50	191	137	149	286
EQUIP'T CONTRACTORS — B				4				09			27			82			24	
EQUIP'T CONTRACTORS — A				32				81			25			746			237	
EQUIP'T CONTRACTORS — T	30	0	30	52	4	56	75	9	84	110	28	138	146	83	229	·142	261	403
MAT INCL FUEL INV — FABR & DELIVERY	215	0	215	394	21	415	583	54	637	848	166	1014	1130	506	1636	1102	1622	2724
MAT INCL FUEL INV — ERECTION	73	0	73	137	8	145	201	22	223	292	67	359	392	200	592	380	658	1038
OWNERS CONTINGENCY & OVHD	55	0	55	102	9	111	150	22	172	216	64	280	296	182	478	282	554	836
TOTAL	398	0	398	735	44	779	1081	113	1194	1570	342	1912	2105	1021	3126	2043	3244	5287
DOLLARS PER KW	71		71	71	220	74	72	188	76	72	160	79	71	142	85	70	119	93
FUEL BURNING & STEAM GEN UNITS ONLY — ENG DESIGN DEV EQUIP'T CONTRACTOR	10	0	10	19	3	22	28	6	34	41	20	61	55	58	113	54	184	238
MATERIALS FABR DEL	81	0	81	151	14	165	211	38	249	320	116	436	432	355	787	430	1135	1565
ERECTION	47	0	47	87	6	93	128	15	143	185	45	230	251	140	391	249	460	709
TOTAL	138	0	138	257	23	280	367	59	426	546	181	727	738	553	1291	733	1779	2512
DOLLARS PER KW	25	0	25	25	115	27	24	98	27*	25	82	30	25	77	35	25	65	44

* USE 40 YEAR REPLACEMENT AGE FOR "F" EQUIPMENT
USE 10 YR REPLACEMENT AGE FOR 1970 "N" EQUIPT, 15 YR FOR 1975 "N" EQUIPT, 20 YR FOR 1980 "N" EQUIPT

to the present state of development of nuclear power and must not ignore the capabilities of the competition—conventionally fueled and built steam power plants."

As an example Mr. Davis cited the recently announced Philadelphia Electric Co. plant to operate at 5000 psi and 1200 F with two stages of reheat to 1050 F at a net heat rate of 8400 Btu per kwhr, an efficiency of 40.6 per cent. Only two years ago plants operating at 1500 to 2000 psi and 1050 F with a single reheat to 1000 F were considered examples of advanced design. Such plants have shown actual year-round operating efficiencies of almost 37 per cent.

Further, Mr. Davis commented on the usual practice when comparing nuclear plants as against conventional ones of assuming identical and fairly high load factors for both plants on the premise that both will serve as base-load installations. Actually for base-load service the maximum load factor each plant can achieve should be considered as something of the magnitude of 95 per cent for conventional plants against a still unknown 80 to 85 per cent for nuclear designs. This point indicates a decided advantage for reactors that need not be shut down to replace fuel elements or for reactors where fuel elements can be replaced easily and quickly. This problem of fuel replacement for nuclear reactors is a

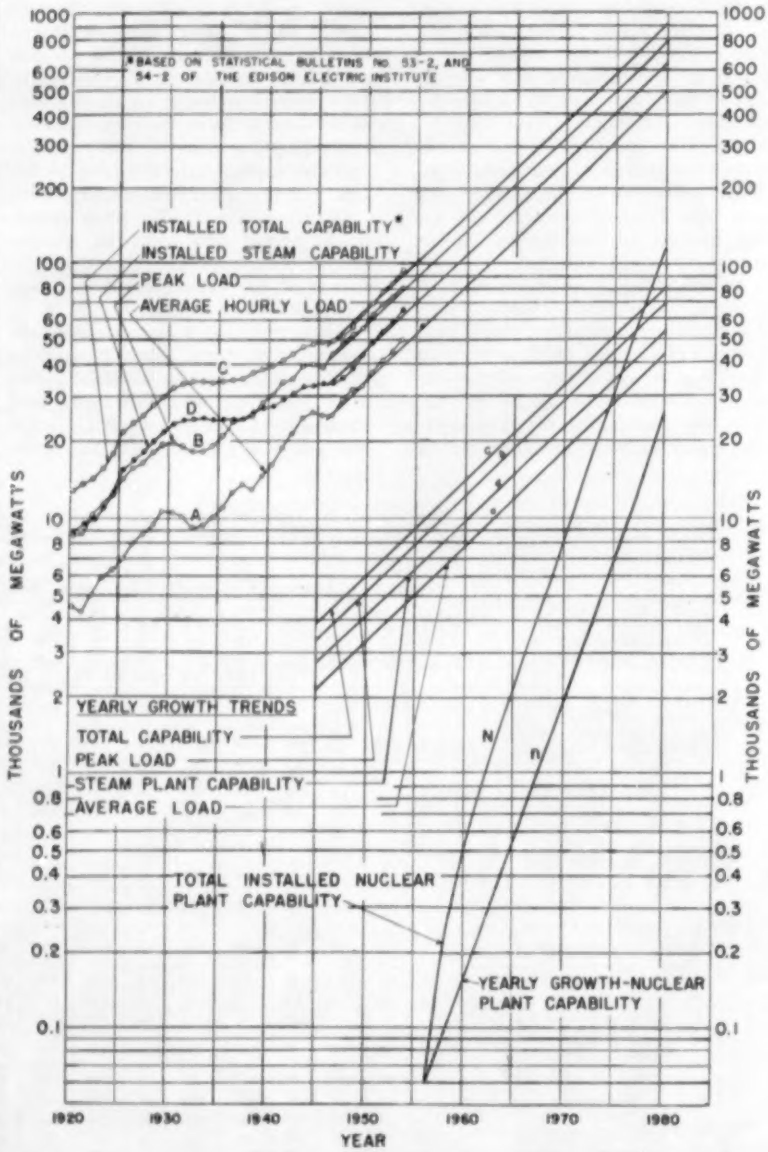


Fig. 1—Growth curves for power needs permit nuclear energy predictions.

very serious and certainly an unsettled one.

The following table summarizes the ratio of costs now attainable for a nuclear reactor plant as against an economically competitive power plant:

	Range	Ave.
Nuclear steam plant		
Construction cost	2–6	4
Useful life	1–2	$1^1/_2$
Fuel elements		
Fabrication costs*	4–20	8
Irradiation life	3–10	5
Overall thermal eff.	$1^1/_4$–2	$1^1/_2$
Nuclear fuel cost†	1	1
Operation & maint. cost	$1^1/_2$–$2^1/_2$	2
Operating factor	1–$1^1/_2$	$1^1/_4$
Processing costs		
Chemical separations	$1^1/_2$–4	2
Water disposal	1–3	2
Overall	2–5	3+

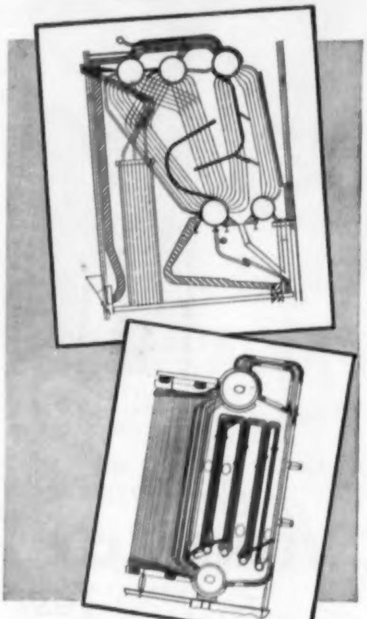
* For high temperatures and long life.
† Assuming recycle of nuclear material as fuel.

Economic Reactor Location

T. G. Le Clair, Commonwealth Edison Co., was one of four speakers handling the general subject of Economic Factors In Locating Reactors. There were five points he advanced as the major ones in affecting power plant location. These included (1) water supply for cooling purposes (estimated at more than 400–500 lb of cooling water for each kwhr generated), (2) proximity to load (cost of transmission alone for large blocks of power ranges up to 3 mills per kwhr for each 100 miles), (3) fuel transport versus electric transmission (the effect of difference between costs of electricity and uranium makes it more attractive to locate the plant as close to the load as possible), (4) effect of plant size (economic considerations point toward large sizes for low unit costs and this means selecting a site in or near a heavy load area), (5) effect of waste products (the subject is still so new for nuclear reactors that there is no accurate way to assess this hazard).

Reactor Designs

Dr. Chauncey Starr, North American Aviation, Inc., felt that the process of selecting the proper nuclear power plant design involves both the problem of time scale and also basic technical philosophy as to the most productive lines of development. The short range possibilities of the sodium graphite reactor as well as its long term promise represents to Dr. Starr's company the best choice at this time.



The twin incentives of a high thermal efficiency and a low capital investment seem possible with a liquid sodium reactor.

Sodium melts at 208 F, is easy to keep liquid in a power plant, has an extremely high thermal conductivity, enjoys fluid dynamics similar to water and a general absence of chemical corrosion in metal systems. Sodium does, though, react chemically with water and oxygen and when exposed to neutrons, as in a reactor, becomes a strong radioactive gamma ray emitter with a half-life of about 15 hrs. This last property, that of induced activity, presents the most serious handling problem for sodium in nuclear power applications.

A further factor that makes the liquid sodium graphite moderated reactor an attractive choice is its inherent safety characteristics. The complete absence of stored energy due to pressure and the absence of chemically reactive substances minimizes the energy for dispersion of radioactive material should there be a failure of the reactor or its auxiliaries. In addition the inherent negative temperature coefficient produces an intrinsic stability that tends to inhibit reactor accidents.

C. R. Barthelmy, Pioneer Service and Engineering Co., reported that the AEC approved study group of which his firm was a member believed these reactors held promise for commercial power service:

(1) The circulating fuel thermal breeder.

(2) Fast breeders with fuel readily adaptable to an inexpensive processing technique.

(3) Sodium graphite reactors with long irradiation time per fuel loading.

Of the above group, the Pioneer Service–Foster-Wheeler–Diamond Alkali group chose to study further the circulating fluid fuel reactor system because it seemed more suitable to large commercial plants, had good general economic prospects and filled the group's choice of "age of development."

This system consists of uranium in a heavy water solution contained in and circulated through a nearby spherical core where the chain reaction occurs. The temperature of the fluid is raised substantially and, as the solution leaves the core, it passes through a gas separator and thence to a heat exchanger where heat is transferred to produce steam used to drive the turbine generator. Having given up its heat, the fuel solution is again returned to the core to repeat the sequence. In the breeder concept a blanket surrounds the core. This blanket may contain thorium in a form which may be circulated. Heat

generated in the blanket in the course of production of uranium from thorium may also be used for steam production.

Dr. Clarke Williams, Brookhaven National Laboratory, described a liquid metal fuel reactor, the LMFR, which it is hoped will generate electric power, breed new fuel for itself and deliver by-products to waste tanks, all in a continuous process. It will be the first usage of a liquid metal alloy, in this case uranium-bismuth, as the fuel stream to interconnect the continuous processes. Fission of the U233 atoms would occur in the core, a perforated graphite sphere five feet in diameter. The molten uranium-bismuth alloy conveys the heat out of the core. Any excess neutrons would be caught in the blanket. The most important feature, though, is the continuous chemical processing.

For example some products of fission appear as gases; part of the molten uranium-bismuth can be piped off for removal of gases such as xenon and iodine by sweeping the liquid metal with an inert gas like helium. In another process liquid salts such as potassium and lithium chloride could draw off fission products while leaving the uranium in the bismuth.

Packaged Power Reactor

Col. James B. Lampert, Atomic Energy Commission, gave the background behind the U. S. Army packaged power reactor. About 100 firms replied to the Dept. of Defense and AEC request for interest in a lump sum contract to develop a relatively small packaged power reactor. These 100 were, in turn, boiled down to 33 qualified bidders and by late November all proposals should be in for final contract award. The objectives of the project are: to demonstrate features and characteristics of a particular nuclear power plant that will permit use in an Arctic environment; to determine the exact economic and operating characteristics of the plant; to determine the reliability of continuous operation; to provide a training facility at Fort Belvoir for military engineers, operating crews and maintenance personnel.

Chris J. Brous, American Machine & Foundry Co., explained that his company's interest in packaged reactors was that they lent themselves to easier use, gave more economical power, had less complex and easier to use nuclear reactor components and systems. The need for small power sources was widespread. Remote areas, the U. S. Army and the metal industry are three distinct markets for the development of this packaged-type reactor.

Waste Disposal

Arthur E. Gorman, Atomic Energy Commission, in a four-man public safety panel tackled the subject of Environmental Problems Ahead for the Atomic Energy Industry. A responsibility of more than average depth rests with all who work in atomic energy development. Highly radioactive gases could be released from a tall stack with no outward evidences of color, odor or other apparent alarm. Similarly radioactive liquid wastes could give off no noticeable physical warnings or affect the biological oxygen demand or upset the dissolved solids balance of a stream. Yet both wastes could be extremely hazardous.

Radiation controls must be rigid and, in certain cases, of long duration. Decisions on disposition of radioactive material call for the best judgment of experts on the effects of radiation, the chemical properties of the isotopes concerned, the characteristics of the wastes as released and their ultimate fate in nature depending on whether release is to the air, ground or surface waterways. The more acute problems start after the fuel elements are irradiated in the reactors, especially those in continuous production or test runs. Today, after ten years of extensive research, the industry has no completely satisfactory disposal method for high level radioactive waters.

Along with the need for a relatively low cost disposal method is the requirement that every precaution be taken against catastrophic accidents. These combined requirements could influence plant location, transportation of fuel elements, handling of waste products. As an example storage of radioactive wastes in underground tanks cost today from $0.35 to $2.00 per gal. In addition there is the constant need for monitoring and, at this moment, the necessity of locating the waste disposal tanks in isolated areas and in soils through which movement, in case of leakage, would be slow. The devices so far considered for containing radioactive wastes fall far short since these wastes have half-lives of hundreds or thousands of years and the containers' life is much, much less. Further the escape of these pent-up isotopes to atmosphere, water or from the ground into foods must be measured against the limits man can tolerate over a life time or for shorter periods.

The Atomic Energy Commission has tried to build a solid base in which future investigations can proceed. Certain soils, notably clays, can absorb considerable radioactive material but not all isotopes.

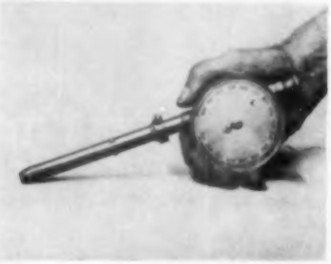
New Equipment

Dealkalizer

Small and medium-sized plants are now offered a packaged dealkalizer employing a strongly basic anion exchange resin that can split salts and substitute chloride anions for bicarbonate, carbonate, sulfate and nitrate radicals. The manufacturers, Cochrane Corp., Philadelphia, Pa., claim that this process of chloride exchange greatly reduces alkalinity without resorting to acids and reduces CO_2 formation in steam. Combined with the manufacturer's Zeo-Flo softener the dealkalizer provides a custom-engineered system at practically stock costs.

Tube Gage

Designed primarily for use in conjunction with tube rolling the Elliott Co., Jeannette, Penna., Tube Gage, recently announced, provides a simple, quick way of accurately measuring inside tube diameters. It features a large dial with graduations especially for heat exchanger and condenser tubes that can be read directly in thousandths of an inch. The gage enables tube expanders and controls to be set accurately for tube rolling.



Three hardened steel balls protrude from a hollow steel barrel to give the necessary three-point contact essential for accurate tube measurement. These balls are supported by a spring-loaded, tapered mandrel that moves inside the barrel. To use the gage the mandrel is partially withdrawn by pulling out the knob to let the balls recede. The gage is then inserted and the mandrel slowly released. The tube inside diameter is thus read directly from the dial.

Final Drive Unit

A high torque, special drive unit known as the Forced Drive Unit, can supply a starting torque in excess of 4000 lb for positioning of valves and fans in outdoor boilers or handling heavy doors and other equipment in steel mills. The device, manufactured by Republic

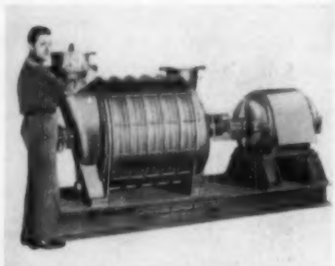
Flow Meters Co., Chicago, Ill., is pneumatically powered, enclosed in a weatherproof housing and, with a thermostatically controlled heater that can be furnished, it will assure positive operation in cold weather.

Needle Valves

A complete, new line of forged needle valves with universal outlets featuring micrometer thread, stainless steel stems has been announced by the Carpenter Valves Corp., Cleveland, Ohio. The product, known as Bull-Dog valves, are forged from brass, stainless steel or carbon steel and a wide range of optional machinings are available for the outlets.

Centrifugal Blower

A multistage, standard production blower, the No. 385 frame unit, now available from U. S. Hoffman Machinery Corp., New York, is capable of delivering between 1500 and 3500 cfm with pressures ranging from 1- to 9-psig or vacuums from 2- to 12-in. Hg.



The new blower employs a combination of two interchangeable impellers so customer's needs can be individually met with factory-assembled units that are self-adapting to variations in air volumes from minimum to maximum capacity.

Smoke Comparator

A field-glass-like smoke-comparing instrument, the Smokescope, available from the Mine Safety Appliances Co., Pittsburgh, Penna., admits light from the area adjacent to a stack through one tube of the field glass assembly where it goes through a reference film disk to a front surface mirror, and then through a lens to an image mirror where it can be directly compared with the smoke from a stack as seen through the other tube of the field-glass holder.

The manufacturers claim the device has received considerable field trial and overcomes the major disadvantages of the classical Ringelmann chart.

Proportioning Pump

Special high-speed valves, pulse-free flow, and no packing feature the Hills-McCanna-Meter proportioning pump

recently demonstrated by the Hills-McCanna Co., Chicago, Ill. It is a fully enclosed, positive displacement design that will precisely meter quantities from 5 cc to 6 gal per hr per feed at standard speeds from 27 to 900 strokes per minute. Gases and vapors are vented automatically. Standard units will develop pressures up to 2500 psig.

The pumping element is sealed and there are no packing glands or stuffing boxes. Regulation can be under automatic control using direct instrument air signals. The valves are a high-speed type with special valve and seat surfaces so that they are fast-acting, positive seating and self-cleaning.

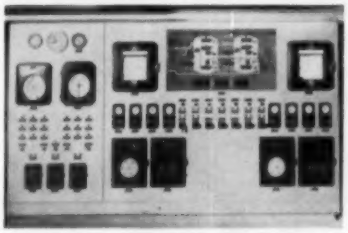
Temperature Scanning

Thomas A. Edison, Inc., West Orange, N. J., reports through its Instrument Div. that their Omniguard, a temperature monitoring system, is the simplest and most flexible available. It has been assembled on a building-block design so that it is a complete system whether 4 points are installed or 400 points. An original installation of 4 points can be raised by adding additional units without disturbing or affecting the existing units or wiring.

The Omniguard monitor units can be mounted close to the equipment and supply a master alarm signal through a pair of copper wires connecting to a central control room. The unit operates without moving parts, has no electronic components, requires no adjustment after initial temperature setting of each point has been accomplished.

Graphic Panel

In addition to the usual controls, meters and recorders a pictorial representation of the ion exchange units and the immediate piping and valves show on the graphic panel control board for automatic ion exchange equipment now available from the Graver Water Conditioning Co., New York, N. Y.



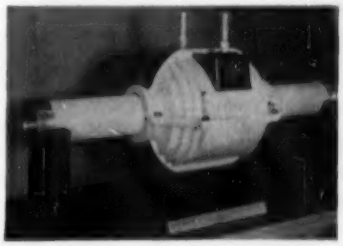
Each valve representation has two colored lights, one red, one green. When the operation valve is open the green light is on, when the valve is closed the red light is on. All pipe lines are also lit and colored with a different color for each material such as acid, caustic, inlet water and outlet water.

Underfeed Stoker

A package type, bin-fed, single retort, Ramfeed stoker of the Canton Stoker Corp., Canton, Ohio, incorporates the manufacturer's Flo-Tube conveyor with the company's regular line of stokers. The combination supplies coal direct from coal storage to the furnace without manual attention. It is dust free and when equipped with bin level controls automatically starts when the hopper is empty and stops when it is full.

Magnetic Flowmeter

Incorporating all the unique advantages of electromagnetic metering a new flowmeter designed for 2- to 8-in. flow lines by the Foxboro Co., Foxboro, Mass., measures the volume flow rate of any liquid of sufficient conduction and velocity. Unaffected by pressure, viscosity, density and changes in conductivity of the flowing liquid the equip-



ment makes practical a number of flow measurements impossible with ordinary metering equipment.

The unit consists of a non-magnetic flow tube with an insulating line containing flush-mounted metallic electrodes and surrounded by an ac electromagnet. Overall accuracy is within plus or minus one per cent of the scale span from maximum flow down to zero flow despite factors of turbulence and dirty flow. The meter presents no more pressure drop than a length of pipe equivalent to the meter tube. Complete specifications are available in a technical report, TI 27-A-71a.

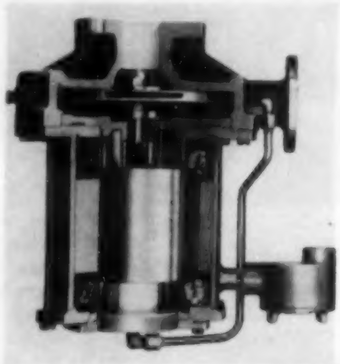
Control Station

Vital operating indicators and controls for pneumatic systems can now be concentrated in the Bailey Meter Co.'s (Cleveland, Ohio) Mini-Line control station. With it an operator has the choice of remote manual control independent of all automatic controllers for start-ups and shutdowns and for periods where the measuring or the controlling elements may be out of service.

Vertical gages indicate signals from the transmitter, set point or bias, hand control and automatic control. The three control knobs are for automatic hand selection, set point or bias adjustment and hand control. Gage accuracy is within $\pm 1/2$ per cent of signal range, and air consumption is less than 0.2 cfm.

Chemical Pump

Totally enclosed, "canned rotor," sealless, leakproof centrifugal pump, the Chempump, manufactured by Chempump Corp., Philadelphia, Penna.



allows the pumped fluid to enter the rotor chamber so stuffing boxes and packing glands are not needed. A stainless steel liner, inserted in the air gap of the motor isolates the stator section. Units are available in cast iron, stainless steel and Monel construction.

Sizes range from $1/8$- to 3-hp with capacities up to 180 gpm at heads up to 90-ft. Today's designs can handle fluid at temperatures to 450 F and pressures up to 150 psi. Simple modifications permit pumping at temperatures to 600 F and at pressures to 5000 psi.

Pipe Covering

Baldwin Hill Co., Trenton, N. J., recently added to its line of insulating materials, 85 per cent magnesia and calcium and silicate. The calcium silicate pipe covering applies for temperatures up to 1200 F and can withstand these higher temperatures without fusing, oxidizing or materially changing shape. By combining the high temperature calcium silicate to the low thermal conductivity of 85 per cent magnesia all pipe sizes and thicknesses can be provided.

Liquid Level Control

A new standard of flexibility, long life and maintenance-free operation are the strong claims made by Photoswitch, Inc., Cambridge, Mass., for their probe fittings, series 67, designed for use with Photoswitch level controls. These fit-

tings eliminate the need for stuffing boxes, floats or any moving parts. The liquid under measurement provides a path for a minute electric current which actuates the level control to start or stop pumps, sound alarms or perform any other control function.

Slag Breaker

Modern pulverized-coal-fired slagging or wet bottom furnaces with continuous discharge of molten ash frequently suffer from stalactites that form and hang from the furnace bottom outlet. These

stalactites grow to clog the slag outlet. A new device, an automatic operating slag breaker, has been developed by the United Conveyor Corp., Chicago, Ill., to mechanically and automatically break and knock down this slag formation and preclude the possibility of plugging the furnace discharge outlet.

Scale Thickness

An electrical instrument for measuring the thickness of scale or other deposits on the inside of boiler tubes, waterwall tubes or other straight or bent tubes or ducts of circular cross-section is available in the Turner scale Thickness Indicator, manufactured by Haskins Turner Co., Jackson, Mich.

The device works on an electromagnetic induction principle and is independent of the deposit material. A probe head is fed down the tube by means of a steel tape. The indicator is available for tubes from $1^1/_2$-in. to 4-in. I.D. with special sizes on request. It uses 110 to 210-v, 60-cycle, ac supply.

Polyvinyl Chloride Valve

In response to a demand for additional corrosion-resistant materials the Hills-McCanna Co., Chicago, Ill., added polyvinyl chloride bodies to their

Saunders patent diaphragm valve line. Hand-wheel operated, lever-operated, sliding stem and air-operated types are available at sizes ranging from $^1/_2$-through 2-in. piping. Screwed ends are standard and slip fits are available on special order.

Water Diffusers

To prevent windrowing and shifting of ion exchange resins beds Permutit Co., New York, N. Y., have devised special plastic diffusers, made of perforated cylinders about 6-in. diam. by 5-in. high, tapped and threaded for a standard pipe connector. Water flow-

ing into the diffusers under pressure and passing outward through the perforations is thoroughly diffused.

In the manufacturer's industrial cation and anion exchanger units, 54-in. diam and larger, these diffusers have been applied to the inlet distribution system. For hydrogen cation exchangers and anion exchangers these devices are fabricated from an inert plastic such as methyl methacrylate.

Conveyor Idler

A cable-suspension idler for belt conveyors known as the Limberoller, manufactured by Joy Mfg. Co., Pittsburgh, Penna., uses only two bearings and carries the belt on resilient, pressure-molded neoprene disks, all of the same size and all revolving at the same peripheral speed.

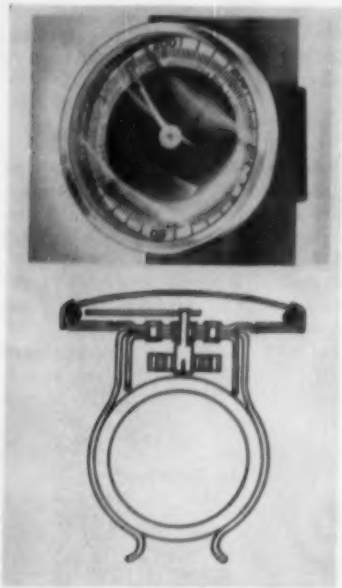
The new device permits conveyor heights from $13^1/_4$- to $15^3/_4$-in. and is available for belt widths of 24-, 30- and 36-in.

Hose Couplings

A complete line of quick-seal, leakproof hose couplings with built-in single or double check valves is now available from Titeflex, Inc., Newark, N. J. The built-in check valves eliminate the need to shut down pumps or close valves to break a connection so that valuable or hazardous fluids are not lost when the line is opened.

Surface Thermometer

Pipes from $^1/_2$- to 2-in. size can have their temperatures read by means of a



Surface Thermometer developed by by Pacific Transducer Corp., Los Angeles, Calif. The thermometer clips to the pipe without tools and is held by spring-action. The temperature-sensitive element is a calibrated bimetal that is closely coupled thermodynamically to the pipe. The accuracy of the 2-in. thermometer dial is plus or minus two degrees over the entire range. The thermometer which comes in two ranges −50 to 250 F and 70 to 370 F, reaches stability within five minutes.

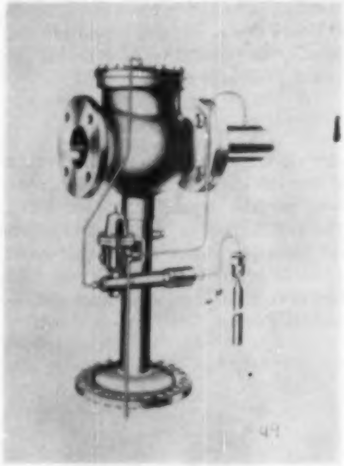
Float Trap

A simplified, low cost, float trap to handle gas, air and steam applications has been placed on the market by the V. D. Anderson Co., Cleveland, Ohio. The trap, known as No. 81, consists of a stainless steel valve and seat, and lever, plus a copper hide float inside.

Combined Control Valve

A single main valve that gives both pressure and temperature control in ranges from 15 to 125 psi has been announced by Klipfel Valves, Inc., Hamilton, Ohio. The new valve, No. 1649, is said to prevent hunting, cycling or overheating of valves with temperature control only. The temperature adjustment range is 50 F. The standard temperature arrangements are: 25 to 75 F, 75 to 125 F, 125 to 175 F, 150 to 200 F, 175 to 225 F and 225 to 275 F.

Valve sizes over 2-in. have semi-steel bodies; smaller sizes have bronze bodies. Stainless steel trim is employed in sizes 4-in. and smaller while larger sizes use



bronze trim as standard. Eight feet of capillary tubing and a nickel-plated bulb is standard in all sizes.

Solenoid Valves

A new line of pilot-operated solenoid valves now marketed by O. C. Keckley Co., Chicago, Ill., are designed for steam service at pressures to 250 psi and air, water, oil or gas to 600 psi at pipe sizes from $^1/_2$- through 6-in.

Valve bodies are bronze or semi-steel, with the pilot valve, main valve and seat of stainless steel. Solenoid coils are glass-insulated, heavy-duty, moisture-proof type for high pressure and temperature service.

BOOKS

1—Mechanical Engineering Thermodynamics

By David A. Mooney

540 pages Price $9.35

A vast amount of very readable information is contained in the 540 pages of this book. While written primarily as an instruction text, it is also well suited to the needs of the practicing engineer as a reference book.

Although a limited amount of elementary calculus has been employed, principally in connection with process calculations, this need not detract from the readability of the text by those who may have become rusty in mathematics, for the various explanations are clear.

The first and second laws of thermodynamics are explained at length, and the twenty-five chapters include those on properties of pure substances, gases and steam; also discussion of various cycles, nozzles and orifices, steam turbines, internal-combustion engines, gas turbines and refrigeration. All of these are amply illustrated by diagrams, and the text is in line with up-to-date practice as concerns pressures, temperatures and reheat.

An appendix contains tables on different gases, combustion data, conversion units and specific heats of gases, as well as properties of air, steam, ammonia and mercury. Also, a number of large working charts are contained in a jacket. These deal, in part, with pressure-enthalpy for freon, temperature-entropy for air, a Mollier diagram for steam, temperature-entropy for CO_2, products of combustion and theoretical fuel-air mixtures.

2—High-Temperature Alloys

By Claude L. Clark

383 pages Price $7.50

This is a book intended for those who develop and use high-temperature alloys. It is also suitable for use as a text and reference book and should be of considerable assistance to those organizations having high-temperature testing laboratories. The approach is basically a metallurgical one.

An introductory chapter takes up industrial trends which have prompted interest in high-temperature alloys. Next are considered the mechanism of plastic deformation, desirable qualities for high-temperature service, and methods of testing. Considerable attention is given to creep strength and to methods for evaluating load carrying ability. The largest portion of the book concerns properties of various alloy steels, including low and intermediate alloys, stainless steels, bolting steels and those for extreme high-temperature service. There is a very interesting chapter covering nine types of service failures. Concluding chapters take up physical constants, properties at hot-processing temperatures, selections of material for specific applications and typical specifications and codes covering high-temperature.

3—Power Plant Engineering 3rd Edition

By Frederick T. Morse

687 pages Price $8.75

Subtitled "The Theory and Practice of Stationary Electric Generating Plants," the drastically revised Third Edition of this well-known text attempts to meet the needs of the engineering student, the consulting engineer and the plant operator. Emphasis is placed upon the power plant as an integrated assembly, and there is more attention given to the small plant than was the case in previous editions. The author provides the following basic definition.

"Power plant engineering is the art of selecting and placing the necessary power-generating equipment so that a maximum of return will result from a minimum of expenditure over the working life of the plant; and the operation of the completed plant in a manner to provide cheap, reliable and continuous service."

An introductory chapter provides background information on thermodynamics and gives a description of the function of consulting engineers in power plant design. Subsequent chapters take up the variable load problem and power plant economics, including depreciation methods and an introduction to rate making. Following this general presentation are chapters on the power plant building, fuels and combustion, internal-combustion-engine and gas-turbine power plants, vapor cycles and energy flow, steam generators and prime movers, gas and feedwater loops in steam plants, piping systems and instrumentation. At the end of most chapters is a set of problems without answers. A brief bibliography and an appendix conclude the work.

4—Pumps 2nd Edition

By F. A. Kristal and F. A. Annett

Price $6.50

This book covers pumps of many types and designs, how to select and install them, how to operate and maintain them, and how to locate and remedy pump troubles. Intended for use by designers, manufacturers, sales representatives and operators, it discusses a wide range of pump applications, including boiler feed, paper stock, deep-well, sewage and sludge, chemical, food product, oil field, gasoline line, fire, mine, etc.

Performance features of the various types are explained, as are their service limitations. Likewise covered are construction features, the materials used in manufacture, and the operations of particular types. In addition, practical methods are given for fiugring the head, economical pipe sizes, various combinations, etc.

This completely revised edition covers new designs, materials and applications developed since the first edition, including the latest technical advances in diaphragm, variable-displacement, proportioning, self-priming, regenerative turbine, rotary, jet and many other types.

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Buell offers you a unique opportunity to eliminate nuisance dust problems . . . without risking a single cent!

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MECHANICAL ELECTRICAL

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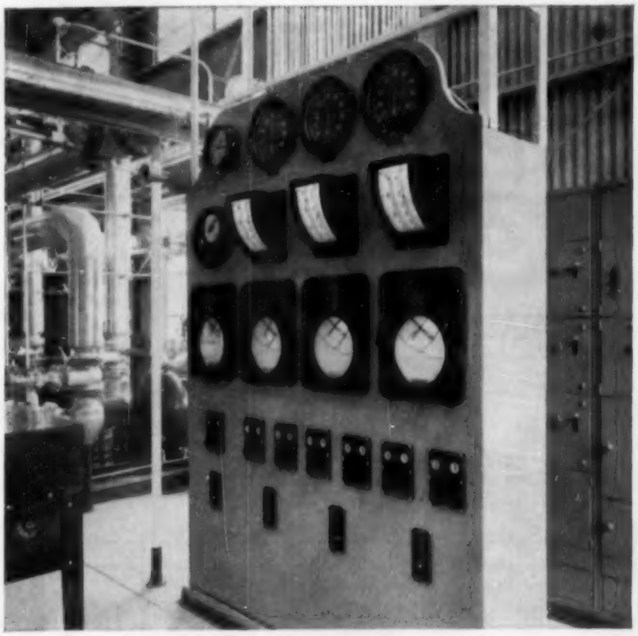

Bailey Boiler Control Panel for three 150,000 lb per hr, 400 psi, gas-fired boilers. Meter at left records total Steam Flow; the other three meters record Gas Flow—Air Flow and Flue Gas Temperature.

How to Control Steam Costs

★ Close regulation of fuel and air input is vital to a strict control of your steam cost. But that's not all. You'll need control of other factors, too. Your costs can be held down only by controlling all of the important operations in your steam plant. That's where you can be sure of help from Bailey Controls. Here's why they can do the job and do it right:

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When you receive equipment recommendations from a Bailey Engineer his selections come from a complete line of well-engineered and carefully tested products.

2. Seasoned Engineering Experience

Your local Bailey Engineer brings you seasoned engineering experience based on thousands of successful installations involving problems in measurement, combustion, and automatic control.

3. Direct Sales-Service—close to you

For your convenience and to save time and travel expense there's a Bailey District Office or Resident Engineer in or close to your industrial community.

For greater fuel savings, less outage and safer working conditions, you owe it to yourself to investigate Bailey Controls. Ask a Bailey Engineer to arrange a visit to a nearby Bailey installation. We're glad to stand on our record.

A-125-1

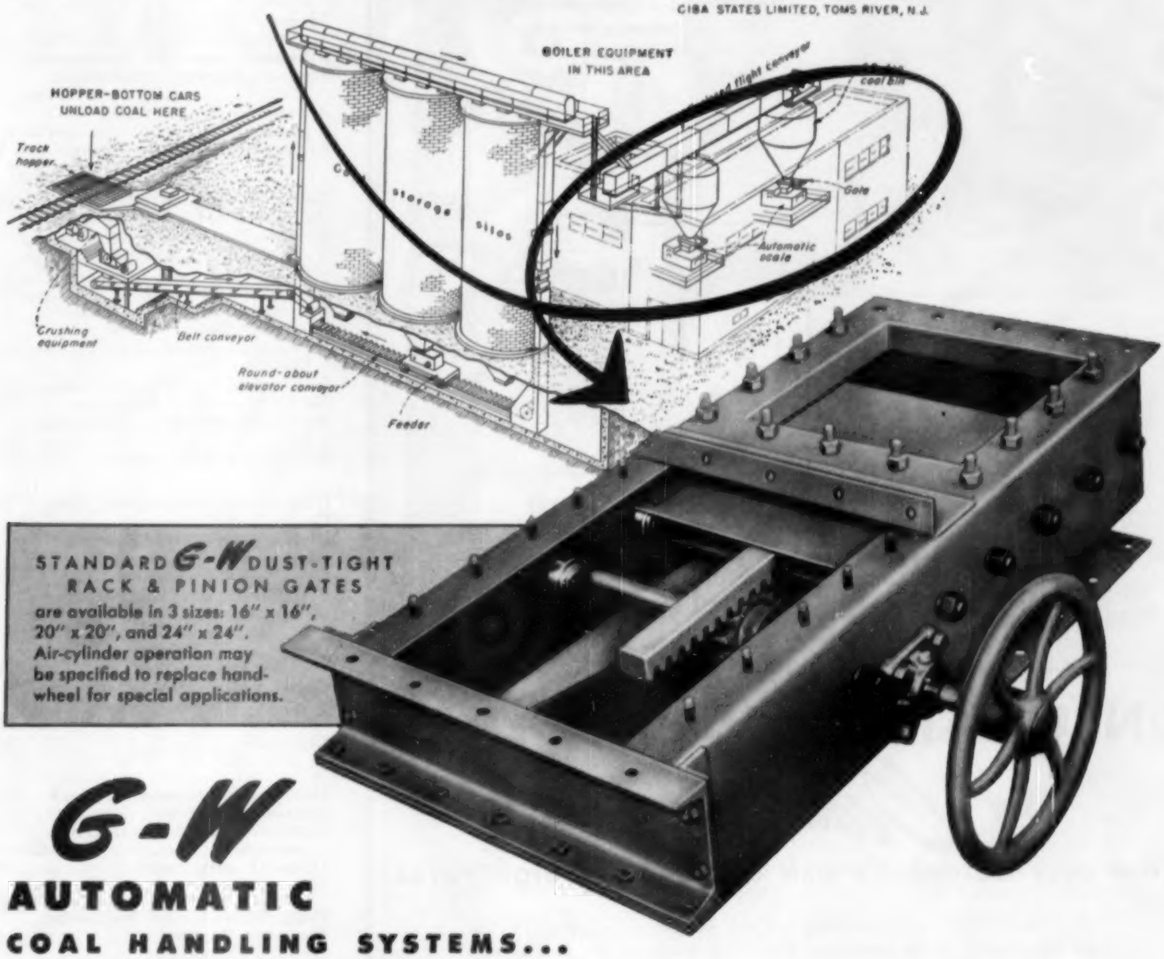
FORMULA
for Cutting Steam Costs
•
+ Bailey Design
+ Bailey Engineering
+ Bailey Service
= Greater Savings per Fuel Dollar

BAILEY
METER COMPANY
1025 IVANHOE ROAD
CLEVELAND 10, OHIO
Complete Controls for Steam Plants

Controls for
COMBUSTION
FEED WATER
TEMPERATURE
PRESSURE
LIQUID LEVEL
FEED PUMPS

from Receiving Grate ... to Discharge Gate

GIFFORD-WOOD COAL HANDLING SYSTEM AT CIBA STATES LIMITED, TOMS RIVER, N.J.



STANDARD G-W DUST-TIGHT RACK & PINION GATES are available in 3 sizes: 16" x 16", 20" x 20", and 24" x 24". Air-cylinder operation may be specified to replace hand-wheel for special applications.

G-W AUTOMATIC

COAL HANDLING SYSTEMS...

engineered for efficiency

This Rack and Pinion Gate is typical of G-W attention to engineering detail. It's the last piece of equipment in the complete G-W Automatic Coal Handling System in the huge new plant of Ciba States Limited, Toms River, N. J.

Through two of these gates pass all the coal used by this large processing plant. They absorb tons of pressure—day in, day out. Yet the rugged all-welded construction of the gate housing gives complete protection to all parts and traps all coal dust. Turning the handwheel moves the slide plate over sturdy roller bearings through a simple rack and pinion mechanism. Simple design?—Yes... but the very efficiency of this gate lies in its *engineered* simplicity... the Gifford-Wood way.

GIFFORD-WOOD CO.

Since 1814
Hudson, New York

New York 17	St. Louis 1	Chicago 6
420 Lexington Avenue	Railway Exchange Building	565 W. Washington Street

6009

When you think of ENGINEERED Materials Handling ... think of Gifford-Wood

Advertisers' Index

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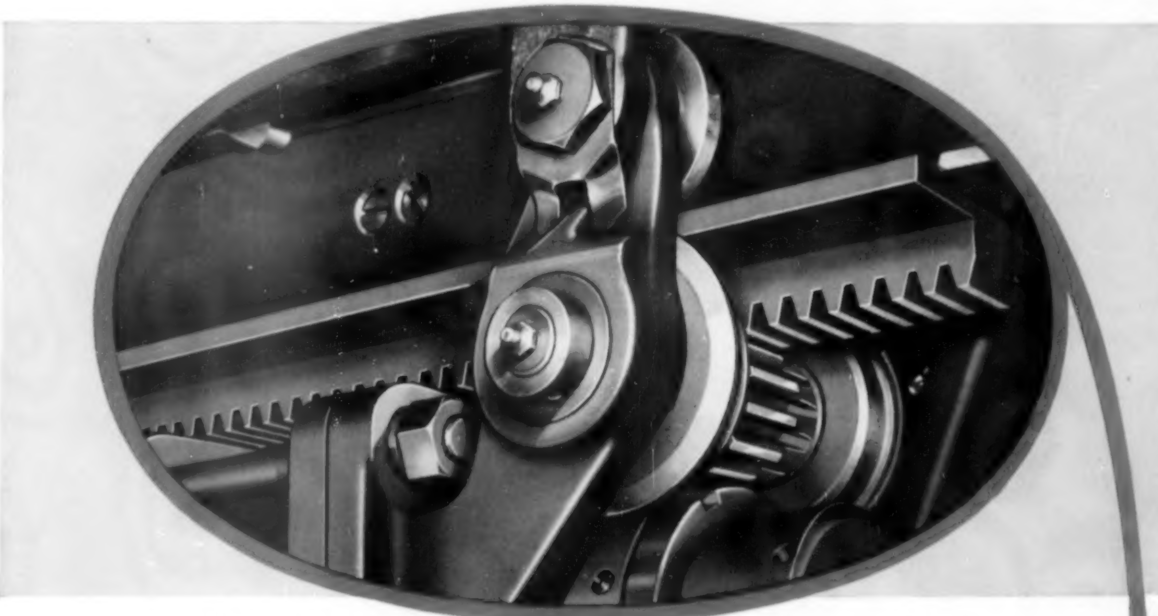
POSITIVE GEAR DRIVE



Another Reason for the SUPERIOR PERFORMANCE of DIAMOND Model IK LONG TRAVEL RETRACTING BLOWERS

The lance tube of the Diamond Model IK Long Retracting Blower is propelled into the furnace by the carriage which is driven by a rugged pinion gear which engages a heavy rack. Gearing will stall lance in event of motor drive failure during blowing. This represents the ultimate in safety and reliability.

This is only one of several reasons for the superior performance of the Model IK. Others are the single motor drive (one motor simultaneously propels the carriage and rotates the lance) . . . mechanically operated poppet valve which provides simple, positive and accurate control of blowing medium (air or steam) . . . integral adjustable pressure control.

Advanced engineering features such as these, plus reliability proved over the years, are important reasons why the great majority of engineers prefer Diamond Blowers.

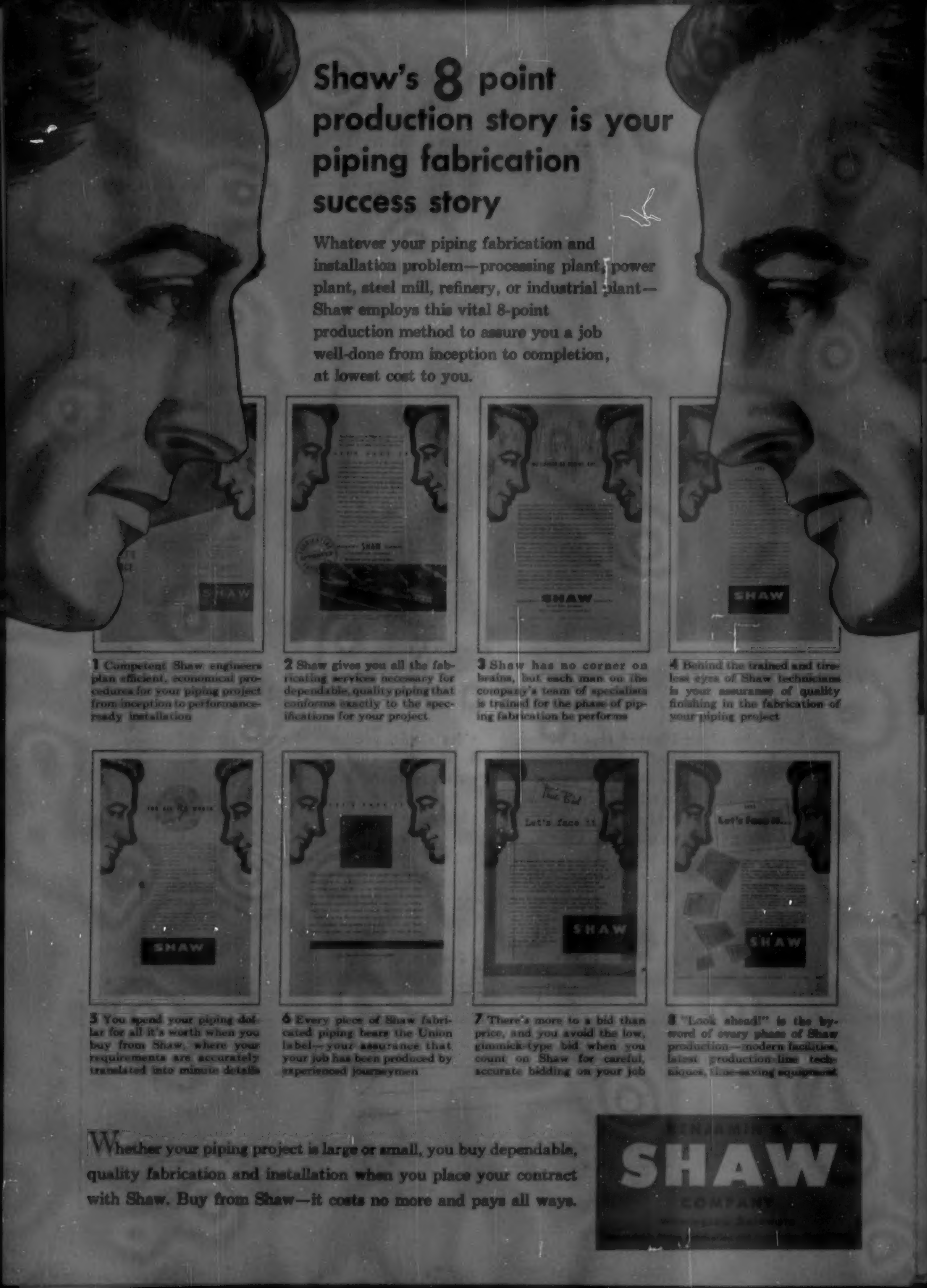
DIAMOND POWER SPECIALTY CORP.

LANCASTER, OHIO

Diamond Specialty Limited • Windsor, Ontario

6704

Diamond Model IK Long Travel Retracting Blower with single air motor drive. Single electric motor drive also available.


Shaw's 8 point production story is your piping fabrication success story
Whatever your piping fabrication and installation problem—processing plant, power plant, steel mill, refinery, or industrial plant—Shaw employs this vital 8-point production method to assure you a job well-done from inception to completion, at lowest cost to you.
1 Competent Shaw engineers plan efficient, economical procedures for your piping project from inception to performance-ready installation
2 Shaw gives you all the fabricating services necessary for dependable, quality piping that conforms exactly to the specifications for your project
3 Shaw has no corner on brains, but each man on the company's team of specialists is trained for the phase of piping fabrication he performs
4 Behind the trained and tireless eyes of Shaw technicians is your assurance of quality finishing in the fabrication of your piping project
5 You spend your piping dollar for all it's worth when you buy from Shaw, where your requirements are accurately translated into minute details
6 Every piece of Shaw fabricated piping bears the Union label—your assurance that your job has been produced by experienced journeymen
7 There's more to a bid than price, and you avoid the low, gimmick-type bid when you count on Shaw for careful, accurate bidding on your job
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